Assessment of Thornyheads (*Sebastolobus spp.*) in the Gulf of Alaska

By
Sarah Gaichas and James N. Ianelli

Executive Summary

This year we updated the model introduced in 1997 with available recent data, including 2002 harvest levels by gear, biomass and length frequency from the 2003 Gulf of Alaska bottom trawl survey, and relative population numbers from the 2003 sablefish longline survey. Alternate models examined assumptions regarding natural mortality and length at age. Results from this year's base model analyses suggest an increasing biomass relative to last year's assessment. Accordingly, projected harvest levels are higher under the maximum permissible $F_{40\%}$ fishing mortality. The following summarizes the (base model) ABC recommendations and status of spawning biomass level for the past few years relative to the current assessment:

Assessment Year	Projection Year	Female spawning biomass	ABC Recommendation
2001	1997	22,289 t	
2001	1998	22,521 t	
2001	1999	22,792 t	
2001	2000	22,996 t	
2001	2001	23,150 t	
2001	2002	23,235 t	**2,494 t**
2002	1997	22,579 t	
2002	1998	22,813 t	
2002	1999	23,084 t	
2002	2000	23,286 t	
2002	2001	23,436 t	
2002	2002	23,549 t	
2002	2003	23,567 t	**2,555 t**
2003	1997	24,356 t	
2003	1998	24,664 t	
2003	1999	25,011 t	
2003	2000	25,291 t	
2003	2001	25,519 t	
2003	2002	25,709 t	
2003	2003	25,975 t	
2003	2004	26,202 t	**2,945 t**

Summary of major changes

There are no changes to the assessment model. New biomass, abundance, and length information from the Gulf of Alaska bottom trawl survey and sablefish longline survey are incorporated. New fishery catch and length information is included. Some adjustments to input catch data resulted from an updated query of both the BLEND and observer databases. This updated information lowered discard levels from the longline fishery in the mid 1990s and also reduced the amount of length data available from both trawl and longline fisheries.

The 2003 survey data suggest a moderate increase in abundance over that estimated last year. The ABC value using the base model provides nearly a 20% increase in ABC as shown above. However, because

there has been a level of discomfort with the natural mortality estimated by the base model (which provides the best fit to the limited available data), this year we propose an alternative ABC and OFL based on Tier 5 criteria. The average of the two most recent complete GOA trawl survey biomass estimates (1999 and 2003), 86,200 t, multiplied by M=0.03 times 0.75 gives an **ABC of 1,940 t** and an **OFL level of 2,586 t**. This option may be preferable given the level of uncertainty in the apparent model inconsistencies (i.e., general lack of bigger or older fish expected if M truly is as low as 0.03).

Response to SSC comments

(From December 2001) *The SSC received a report from Sarah Gaichas on the status of stocks of thornyhead rockfish. Model estimates of natural mortality rates seemed high to the SSC in part because they exceed rates for Pacific ocean perch a species with lesser longevity. We suspected that the model might be reacting to a truncated age distribution from the fishery. Thornyhead rockfish are known for their size and age stratification by depth (i.e., their bathymetric demography). For the population along the Pacific coast (WA, OR, CA) smaller fish are typically found on the shelf and larger fish along the slope. We recommend that stock analysts explore the bathymetric demography of the species in Alaskan waters, and evaluate whether the catch-at-age data are appropriately stratified to reflect thornyhead size and age stratification.*

This year's assessment retains the age length key based on radiometric age information, and further explores natural mortality assumptions by adjusting the prior assumption for M. We present results from an alternative model that estimates a lower natural mortality rate than the base model presented last year. Fishery catch at size information (there is no catch at age data) is available for trawl fisheries, which account for approximately half of thornyhead catch but tend to take place in shallow depths relative to longline fisheries. As in 2001 and 2002, length information from the longline fishery was of limited use in examining distribution by depth because less than 40 fish were measured from the fishery in 2003. New information from the 2003 Gulf of Alaska bottom trawl survey was incorporated. The fact that there is no directed fishery (as in WA, OR, and CA) for shortspine thornyheads the GOA precludes detailed analysis on the fishery aspects of size or age patterns with depth. Earlier investigations of shortspine thornyhead size at depth patterns using longline and trawl survey data showed a similar pattern to that found in other areas and for this reason, selectivity estimates are modified accordingly (i.e., a different selectivity pattern is used for years when the survey failed to sample deep strata). However, the differences in selectivity estimates for this scenario were found to be minor and could reasonably be captured by a different estimated catchability value for years when the survey was incomplete.

Introduction

The shortspine thornyhead (*Sebastolobus alascanus*) inhabits deep waters from 92 to 1,460 m from the Bering Sea to Baja California. Thornyheads are abundant throughout the Gulf of Alaska and are commonly taken by bottom trawls and longline gear. In the past, this species was seldom the target of a directed fishery. Today thornyheads are one of the most valuable of the rockfish species, with most of the domestic harvest exported to Japan. The population structure of shortspine thornyheads is not well defined. However, as a matter of practical convenience, thornyheads in the Gulf of Alaska have been managed as a single stock since 1980.

According to Alverson et al. (1964), groundfish species commonly associated with thornyheads include: arrowtooth flounder (*Atheresthes stomias*), Pacific ocean perch (*Sebastes alutus*), sablefish (*Anoplopoma fimbria*), rex sole (*Glyptocephalus zachirus*), Dover sole (*Microstomus pacificus*), shortraker rockfish (*Sebastes borealis*), rougheye rockfish (*Sebastes aleutianus*), and grenadiers (family Macrouridae). Two congeneric thornyhead species, the longspine thornyhead (*Sebastolobus altivelis*) and a species common off Japan, *S. macrochir*, are infrequently encountered in the Gulf of Alaska.

Fishery

As an element of the deepwater community of demersal fishes, thornyheads have been fished in the northeastern Pacific Ocean since the late l9th century, when commercial trawling by U.S. and Canadian fishermen began. In the mid-l960s Soviet fleets arrived in the eastern Gulf of Alaska (Chitwood 1969), where they were soon joined by vessels from Japan and the Republic of Korea.

Thornyhead catches have been reported in a variety of ways. The earliest records available begin in 1967 as published in French et al. (1977). Active data collection began as part of the U.S. Foreign Fisheries Observer Program in l977, when the thornyhead catch in the Gulf of Alaska was estimated at 1,397 t. From l980 on, the observer program has generated annual estimates of the foreign catch of thornyheads by International North Pacific Fisheries Commission (INPFC) statistical area. Since 1983, the observer program has also estimated the catches of thornyheads in the joint venture fisheries. In l984, thornyheads were identified as a separate entity in the U.S. domestic catch statistics.

Estimated thornyhead catches by gear type since 1967 are shown in Table 12.1. Data from 1981 to 1989 are based on reported landings extracted from the Pacific Fishery Information Network (PacFIN) database and the NMFS Observer Program. Before this period, estimates are based on the following reports: French et al. (1977), and Wall et al. (1978-81). Catches in more recent years (1990-1998) are based on "blended" estimates provided by the NMFS Regional Office through the Observer Program. Estimates of discards for these years have been provided as well. The blended and discard estimates are based on a method that makes use of observer data as well as weekly processor reports (WPR). It is interesting to note that for years in which discard information is available, discarding appears to be much more prevalent in the longline fishery than in the trawl fishery. Discards in the domestic fishery before 1990 are unknown. We assumed that the reported catches before 1990 included both retained and discarded catch. Survey research catches of thornyheads (Table 12.2) are a very small component of overall removals.

The catches of thornyheads in the Gulf of Alaska declined markedly in 1984 and 1985 due primarily to restrictions on foreign fisheries imposed by U.S. management policies. The greatest foreign-reported harvest activities for thornyheads in the Gulf of Alaska occurred during the period 1979-83. In 1985, the U.S. catch surpassed the foreign catch for the first time. U.S. catches of thornyheads continued to increase, reaching a peak in 1989 with a total removal of 3,080 t. Catches have since averaged about 1,260 t during the five-year period from 1996 to 2000.

The estimates of discarded shortspine thornyheads has shown a steady decrease in the last 10 years (Fig. 12.1). By weight, the directed fishery for sablefish harvested the largest amount of thornyheads in 2001 and 2002, followed by rockfish and the combined flatfish fisheries (Fig. 12.2). The discard patterns were similar to the retention rates over different fisheries. The spatial distribution of thornyhead catches range broadly throughout the Gulf of Alaska and show consistent interannual patterns for the two main gear types (Figs. 12.3 and 12.4).

Resource Surveys

Longline surveys

Longline surveys were conducted jointly by the United States and Japan in the Gulf of Alaska each year during 1979-1994 to ascertain the abundance level and length composition of important groundfish species in the depths from 101 to 1,000 m. In 1987 a U.S. longline survey was started using similar methodology to the cooperative survey. This survey covered a complete standard area in the Gulf of Alaska beginning in 1990. For each species, the catch rate, the area, and the size composition of samples from each depth stratum were used to determine the relative population number (RPN) and weight (RPW) for each depth stratum. The RPNs and RPWs for the various depth strata (201-1,000 m for thornyheads) were summed to obtain GOA totals (Table 12.3).

The use of the longline survey in general may be questionable because of a possible interaction with sablefish abundance. For example, Sigler and Zenger (1994) found that thornyheads increased in areas where sablefish abundance decreased. They suggested that the increase in thornyhead catch rates between 1988 and 1989 (their data) might be partly due to the decline in sablefish abundance. They reasoned that availability of baited hooks to thornyheads may have increased. Further research is needed on the effect of hook competition between slow, low metabolism species such as shortspine thornyheads and faster, more actively feeding sablefish. The coefficient of variation for the domestic survey index we assumed to be 20%. We present the size compositions from this survey in the section on model fit, below.

The NMFS Auke Bay Lab staff began a feasibility study on tagging shortspine thornyheads from the longline survey in 1997 and have continued to tag shortspine thornyheads on an opportunistic basis. In 2003 they tagged and released 540 shortspine thornyheads bringing the total number of releases up to 3,952. Additionally, they released 56 shortspine thornyhead with electronic (archival) tags to study their depth and movement patterns. This work is part of an ongoing project to learn more about movement and growth rates of this deep-water species.

Trawl surveys

The most recent NMFS trawl survey for the Gulf of Alaska was conducted during the summer of 2003. This survey employed standard NMFS Poly-Nor'eastern bottom trawl gear and provide biomass estimates using an "area-swept" methodology described in Wakabayashi et al. (1985). The 1984, 1987 1999 and 2003 surveys extended into deeper water (>500 m) and covered the range of primary habitat for the shortspine thornyhead stock. The 2001 survey and surveys during the early 1990s did not extend to the deeper zones where concentrations of larger thornyheads are known to exist. This gives survey biomass estimates a disjointed appearance (Fig. 12.5, upper panel). A comparison of survey biomass estimates by depth strata suggests that different portions of the population are sampled depending on survey depth coverage (Fig. 12.5 lower panel). In addition, the 2001 survey did not extend into the eastern Gulf, where a significant portion of thornyhead biomass has been found in past surveys (Fig. 12.5, lower panel). To account for these differences between surveys, we assume that the 1984, 1987, 1999 and 2003 surveys encountered the entire adult population while the 1990, 1993, and 1996 estimates surveyed a smaller portion of the stock. We rescaled the 2001 survey estimate to be equivalent to the 1990–1996 (shallow) surveys by dividing the 2001 estimate from the western and central gulf by the the average proportion of biomass found in the (shallow) western and central gulf in the 1990-1999 surveys. The remaining difference between surveys (deep vs shallow) was accounted for in the model by fixing the catchability coefficient equal to 1.0 for the 1980s and 1999 surveys and allowing separate, freely estimated q value for the 1990–1996 and 2001 surveys. We feel that a significant portion of the biomass of shortspine thornyheads exists beyond depths of 500 m, as illustrated by analysis of longline survey catch-per-unit-effort data (Ianelli and Ito 1994). The ability of our assessment to reflect that actual abundance of shortspine thornyheads is hampered by the lack of reliable data in these deeper habitat areas (and now in the eastern Gulf of Alaska). The spatial distribution of relative thornyhead catch rates observed in the triennial surveys from 1984-1999 suggests lower densities in 1990 and 1993 compared to other years, particularly in the western area (Fig. 12.6). For comparison, the 2001 survey cpue is included.

Analytic approach

In 1997 a sized based, age-structured model was developed and applied to the thornyhead resource in the Gulf of Alaska. In 1998, the original model was re-written in C++ computer language in order to take advantage of analytical software designed for building large, complex models. We use essentially the same model in this assessment, with additional exploration of natural mortality and length at age assumptions.

The conceptual model is similar to that commonly implemented in the stock synthesis program (Methot 1990). Catch data were from 1967 to 2002 with the last twelve years adjusted to include discards. Before this time we assumed harvests of the resource was negligible. Model parameters are estimated by maximizing the log likelihood (*L*) of the predicted observations given the data. Data are classified into different components. For example, size compositions from a survey and from a fishery represent different components. The total *L* is a sum of the likelihoods for each component. The total *L* may also include a component for a stock-recruitment relationship. The likelihood components may be weighted by an emphasis factor. For shortspine thornyheads in the GOA, the model was aggregated to have two fisheries and included the NMFS triennial trawl surveys and the NMFS domestic longline survey. Table 12.4 summarizes the data types used in this assessment. Table 12.5 presents the key equations used for the shortspine thornyheads model in the Gulf of Alaska and a description of key variables is given in Table 12.6. Statistical formulae for the likelihood components are given in Table 12.7.

Parameters estimated independently

Miller (1985) estimated thornyhead natural mortality by the Ricker (1975) procedure to be 0.07. The oldest thornyhead she found was 62 years old. On the U.S. continental west coast, at least one large individual was estimated to have a maximum age of about 150 years old (Jacobson 1990). Another study of west coast thornyheads found a 115 year old individual using conventional ageing methods (Kline 1996). These maximum ages would suggest natural mortality rates ranging from 0.027 to 0.036 if we apply the relationship developed by Hoenig (1983). Recent radiometric analyses suggest that the maximum age is between 50-100 years (Kastelle et al 2000, Cailliet et al 2001), but these are high-variance estimates due to sample pooling and other methodological issues. A recent analysis of reproductive information for Alaska and west coast populations also indicates that shortspine thornyheads are very long-lived (Pearson and Gunderson, 2003). The longevity estimate was based on an empirically derived relationship between gonadosomatic index (GSI) and natural mortality (Gunderson 1997), and suggested much lower natural mortality rates (0.013-0.016) and therefore much higher maximum ages (250-350 years) than had ever been previously reported using any direct ageing method. In past assessments, we attempted to estimate growth within a size-based model using some assumptions from Miller (1985). Here we examine other assumptions about natural mortality and length at age for comparison with the base model, because considerable uncertainty surrounds age and growth parameters for shortspine thornyheads.

In the base model, we use the same age and growth assumptions as in the 1999 assessment by specifying that a 5-year old shortspine thornyhead has a mean size of 15 cm and a 54-year old fish has a mean length of 51 cm. The von-Bertalanfy growth parameter used to “bridge” these mean lengths, *k*, was assumed to be 0.022 based on estimates from past assessments. We selected coefficients of variation in length at age to be 9% at age 5 and 8% at age 54 (based on experience with variability in length-at-age with other rockfish; e.g., Pacific ocean perch). These values were used to create the transition matrix that the model used to convert between modeled numbers-at-age to observed proportions at size.

New length weight information collected during the 1999 Gulf of Alaska trawl survey was used in this assessment. The following length weight parameters were estimated using the nonlinear least squares (nls) function in S-Plus 5 to relate weights and lengths measured for 945 fish:

$$\text{weight (kg)} = a(\text{fork-length(cm)})^b$$

$$a = 3.3549\text{x}10^{-6}, \quad b = 3.3486$$

As in the previous assessment, we chose the size-at-maturity schedule estimated in Ianelli and Ito (1995) for shortspine thornyheads off the coast of Oregon. In this ogive, female shortspine thornyheads appear to be 50% mature at about 22 cm or about 11 years old (Fig. 12.7 top panel). More recent data analyzed in Pearson and Gunderson (2003) estimated length at maturity for Alaska fish at 21.5 cm (although length at maturity for west coast fish was revised downward to about 18 cm). Therefore, we maintained the assumption of a 22 cm length at maturity. These length weight and maturity parameters were unchanged in alternative models.

As presented in last year's assessment, we use the base model to evaluate uncertainties in the estimate of natural mortality (*M*) by selecting a prior distribution rather than assuming a fixed value. Initial model runs using a moderately diffuse (uninformative) prior distribution about *M* indicated that the best fit was attained with a relatively high value of *M* (given constraints placed on declining selectivity with age). Therefore, we selected a relatively informative prior on *M* with an expected value of 0.05 and a coefficient of variation equal to 10% (Fig. 12.8). This resulted in an estimate (0.08) similar to the fixed value assumed in 1998 (0.07) but still allowed for some accounting of uncertainty in this parameter.

Last year we developed two alternative models to examine different assumptions about natural mortality (*M*). In both, natural mortality rates were fixed at a previously defined value, rather than estimated from the data and a prior distribution as in the base model. In the first model, natural mortality was fixed at 0.0129, the value estimated in Pearson and Gunderson (2003) by the GSI regression method for thornyheads in reproductive development stage 5. In the second model natural mortality was fixed at 0.038, an alternative value from the same study. For comparison, all other aspects of the model configuration were kept the same as in the base run. In alternate runs, added constraints on selectivity were included.

This year we retain the model run with M fixed at 0.038, primarily because the Plan Team recommended that ABC be based on that model last year, and the SSC concurred. (We note, however, that Pearson and Gunderson argue that the GSI regression relationships give better support to the lower estimate of M, 0.0129.) The model runs examining *M* assumptions are named "FixM 0.038" for the model that only set *M*, and "FixM 0.038 Sel," for the model that constrained selectivity simultaneously.

Last year, two additional model runs examined alternative length at age relationships. One was based on a recent study by Kline (1996) on west coast thornyheads which used both conventional and radiometric methods to age a relatively large number of fish. With 353 fish, Kline estimated the von Bertalanffy growth parameters Linf = 94.5 cm, k = 0.017, and t0 = -5.52. These parameters were used to generate an age length transition matrix with the same assumptions about variation in length at age (cv of 9% for younger and 8% for older fish) as given above. All of the fish used in this study were collected on the west coast south of Santa Cruz, CA. There may be differences in growth between west coast and Alaska thornyheads (as was found for length at maturity by Pearson and Gunderson; 2003), so we also constructed a second model based on length at age information collected by Kastelle (2000) specific to Gulf of Alaska thornyheads. The disadvantage of Kastelle's data is that the study was less extensive than Kline's and did not include fitting a von Bertalanfy growth function. Therefore, we used the mean length at age for small (average age 5.5, mean length 14 cm, n=45) and large (median age 36, mean length 37 cm, n=41) fish and the *k* parameter estimated by Kline (0.017) to formulate a growth curve. These alternative model runs with different age length transition matrices did not substantially alter the results relative to the base model. Neither model fit the observed length composition data better than the base model, and individual likelihood components appear to trade off improved fits to survey indices with less likely estimates of natural mortality. There is no indication that either of these age length relationships is better than the one in the base model, so we don't re-examine them this year.

This year yet another alternative length at age relationship was constructed based on radiometric age information from Kastelle et al (2000), and length at maturity information from the Pearson and Gunderson study. We assumed that the age at maturity estimated from radiometric data (23.5 years, table 7 in Kastelle et al 2000) would coincide with the length at maturity determined histologically (22 cm). Therefore, the von-Bertalanfy curve was forced though this point by using the t0 and Linf parameters estimated for the Kastelle radiometric data above and adjusting the k parameter. The final "growth" parameters for this model were Linf = 70 cm, k = 0.012, and t0 = -8, and the age length transition matrix was constructed using the same assumptions about variation in length at age as in all other models. All length at age relationships are shown in Figure 12.7. Model runs with this age length transition matrix also included an adjusted length at maturity and weight at age relationship to reflect the length at age assumptions; all other model assumptions including selectivity and priors on M were identical to the base model. Results from this alternative model are presented as "Radio AgeLength."

At the request of the Plan Team, this year several model runs with all base assumptions but changing the prior on M are presented, with M priors ranging from 0.01 to 0.10. Models are labeled accordingly.

Results/Model evaluation

Comparing among these models (Table 12.8), it appears that the available data do not support the low GSI-based estimates of natural mortality (given the other assumptions of the model), nor do they support the radiometric-based age length relationship. (In fact, adjusting the prior for M upwards indicates that within this model structure the data best support a natural mortality rate of 0.102.) With low natural mortality rates specified, the estimates of fishing mortality rates decreased, as did selectivity of older fish in both gear types and longline survey catchability. Fixing *M* to these low values resulted in considerably poorer fits relative to the base model. As expected, low specified values for *M* resulted in a consistent mode of large fish in both survey and fishery size compositions. This is inconsistent with what has been observed. Model runs with strong constraints against dome-shaped selectivity ("FixM 0.038Sel") resulted in lower biomass and yield estimates, still with poor fits to observed size compositions and poor likelihoods. These models predict increasing biomass trends over time, presumably because the old fish do not die off and are not caught in fisheries (or surveys). We note that the predicted yields from the alternative models exceed recent thornyhead catches in the Gulf of Alaska, so if these results were used as a basis for ABC, the effects on the fishery would be minor.

While the total likelihoods and effective Ns indicate poorer support of the data for the FixM and Radio AgeLength models than for the base model, it is interesting that the natural mortality rate estimated by the Radio AgeLength model, 0.037, is very close to at least one M estimated by the GSI method (albiet the weaker estimate). It is clear that there is a conflict between the available catch at size and size at age information and our perception of what M "should" be for this species. The data fit the model best when the prior for M is increased to 0.10 and no other changes are made from the base model (where the prior on M was 0.05.) We also note that some of the data, in particular the longline fishery size composition data which is plagued by extremely low sampling, may not be worth supporting. In addition, the length at age relationship for thornyheads in the Gulf of Alaska is still highly uncertain, which will always be a problem for this assessment until further work on age and growth is completed.

All subsequent results, tables, and figures represent results from the base model configuration. The fits to the observed size composition data for these results were adequate for some years and not so reasonable for others (Fig. 12.9), and the fit to the abundance indices was not particularly good (Fig. 12.10). The trawl survey abundance index was within the observed confidence bounds (see Fig. 12.5). After years of waiting, the base model appears to capture what might be an increasing trend in the longline survey data. The problem remains that the observations do not provide information to suggest whether strong year-classes have occurred. This is due, in part, to the fact that the distribution of thornyheads is widespread and relatively homogenous (i.e., they do not form highly aggregated schools) and because the sample size on length frequency from the fisheries is low. In addition, the ability to obtain a reasonable progression of length modes may be inherently problematic given the slow and perhaps erratic growth of these fish. A sensitivity analyses on the emphasis placed on fitting the longline survey abundance index shows that the overall model fit significantly degrades with increasing longline survey index emphasis (Ianelli and Ito, 1995). Selectivity estimates for the surveys and fisheries are shown in Fig. 12.11.

Abundance and exploitation trends

Results from the base model show that the abundance of shortspine thornyheads has decreased slowly since 1970 and then stabilized (Table 12.9, Fig. 12.12). Fishing mortality rates peaked at about 0.078 in 1989 while for recent years, the rate has remained around 0.034 (Fig. 12.13).

Recruitment

Results from the present study confirm Miller's (1985) suggestion that year class success is variable for shortspine thornyheads in the GOA. Several strong year-classes were apparent but the ability to resolve the precise recruitment year was poor. This is because the thornyheads appear to grow very slowly and have a variable size-at-age relationship that can mask signals of strong year-classes. A plot of the estimated stock and recruitment is very uninformative because of the lack of contrast in spawning biomass levels over the period for which estimates were available (Fig. 12.14).

Projected catch and abundance

Thornyhead exploitable biomass projected to the year 2015, assuming average recruitment of 5 year olds, shows a slow decline when fished at the $F_{40\%}$ rate (Fig. 12.15). Similarly, yields show a slow short-term decline at the $F_{40\%}$ rate (Fig. 12.16). The average recruitment was computed from the period 1967-2001. Although guidelines suggest using recruitment from spawning that occurred from 1977 and later for projecting catch and biomass, we were compelled to use the entire stock assessment period for the following reasons. The model uses 50 age classes and hence responds slowly to variability in recruitment. The time scales of environmental change and harvest projection periods are relatively small. Also, since we examined constant-recruitment scenarios last year as plausible alternatives given available data, the impact of using the entire time series is likely to be minor.

Maximum sustainable yield (MSY) calculations require assumptions about the stock recruitment relationship, which for shortspine thornyheads may be impractical as many functional forms can fit the data equally well. As presented above, the $F_{40\%}$ harvest strategy was selected in the absence of information on the stock-recruitment productivity relationship required for calculating MSY levels.

Reference fishing mortality rates and yields

This assessment uses a time-series of data from several different sources and attempts to provide a comprehensive view of the status of the fishery as well as its history. The values for average fishing mortality and yields are given in Table 12.10 with the historical estimates given in Table 12.11.

Since management of thornyheads is not specific to different types of fishing gear, (i.e., there are no direct allocations of the TAC) the fraction of the TAC harvest by trawl versus longline gear is unpredictable. For our recommendations, we assume that the relative proportions of the SPR (spawning-biomass per recruit) fishing mortality rate in the next year will be similar to the value estimated for 2003. Previously (Ianelli *et al.* 1997) we showed that since the SPR rates are a function of gear selectivity, and the selectivity between trawl and longline gear is quite different, not knowing the relative harvests between gears can be misleading for deriving an SPR rate. For example, longline gear tends to harvest the older segment of the stock, consequently, they are able to harvest at a higher rate and still maintain reasonable spawning stock reserves. Also, please note that we assume that spawning occurs during the month of April (Ianelli *et al.* 1994).

We attempt to present an alternative way to summarize the uncertainty in our yield recommendations. Typically, we estimate the SPR fishing mortality rate (e.g., $F_{40\%}$) by using the fixed assumed (or estimated) values of natural mortality, growth, and fishery selectivity. We then apply this rate to a single (or series of) point estimate(s) of projected stock size to compute the ABC value. This year we devised a method of doing these computations within the estimation framework, thereby enabling us to carry through measures of uncertainty in yield estimates. Without going into detail, this technique involves using the Delta method, also referred to as propogation-of-error. This method presents the uncertainty of *functions* that involve random variables. For example, how does current stock size vary if natural mortality is treated as a random variable? In addition, how do these uncertain quantities affect estimates of yield under the $F_{40\%}$ harvest rate? The result from this application is shown in Figure 12.17. The vertical axis of this figure represents the cumulative odds that the "true" yield at a given SPR rate is less than the value on the horizontal axis. For example, following the $F_{40\%}$ curve along until the horizontal axis reads 1,579 tons gives a vertical scale of 25%. This implies that there is (approximately) a 25%

chance that the "true" yield at the $F_{40\%}$ harvest rate is *less* than 1,579 tons. Interestingly, the "point" estimate of 1,675 tons under the $F_{40\%}$ level coincides with a very minute probability (~3% chance) that the overfishing level ($F_{35\%}$) would be exceeded. This framework can also be used to reflect the uncertainty in future catch by different gear types.

Acceptable biological catch

Although we realize that none of the models are fully satisfactory, all recommendations and projections come from the base model, which explains the data best at the cost of an unpalatable estimate of M. The recommended 2004 $F_{40\%,}$ harvest level (corresponding to full selection F=0.085) for shortspine thornyheads in the GOA is **2,945 t**. This is slightly increased compared to last years's $F_{40\%}$ rate based harvest of 2,494 t. The long-term expected value of female spawning biomass with fishing held at $F_{40\%}$, referred to as the $B_{40\%}$ level, is estimated at about **16,895** t. This is substantially lower than the current estimate of female spawning biomass of **25,975** t. Therefore, under the ABC and overfishing definitions (Plan Amendment 56), no adjustment to the $F_{40\%}$ harvest rate is required.

As an alternative for consideration, the Tier 5 estimate of ABC calculated based on the average of trawl survey biomass in 1999 and 2003 (the most recent complete surveys) and using an M of 0.03 which approximates the GSI-based estimate. Therefore, the Tier 5 ABC is:

$$86{,}200 \text{ t} \times 0.03 \times 0.75 = 1{,}940 \text{ t} .$$

Overfishing level

The Council's overfishing definition is the fishing mortality rate which reduces the spawning biomass per recruit to 35% of its pristine level. For shortspine thornyheads in the Gulf of Alaska that value (averaged over all ages) corresponds to F=0.102 (full selection). This rate corresponds to a catch level of **3,510 t** in 2004, assuming equal catches by gear type.

The alternative Tier 5 estimate of OFL is estimated biomass times M, or 86,200t x 0.03 = **2,586 t**.

Standard harvest scenarios and projections

This year, a standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2003 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2004 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2002. In each subsequent year, the fishing mortality rate is determined based on the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2004, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In all future years, F is set equal to a constant fraction of max FABC, where this fraction is equal to the ratio of the FABC value for 2002 recommended in the assessment to the max FABC for 2002. (Rationale: When FABC is set at a value below max FABC, it is often set at the value recommended in the stock assessment.)

Scenario 3: In all future years, F is set equal to 50% of max FABC. (Rationale: This scenario provides a likely lower bound on FABC that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 1996-2000 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of FTAC than FABC.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Scenarios 1 through 5 were projected 5 years from 2002 (Table 12.12).

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above ½ of its MSY level in 2002 and above its MSY level in 2012 under this scenario, then the stock is not overfished.)

Scenario 7: In 2002 and 2003, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2014 under this scenario, then the stock is not approaching an overfished condition.)

Scenarios 6 and 7 were projected 13 years from 2003 using base model output (Figure 12.18). Under scenario 6, mean biomass projected for 2004 (22,360 t) is greater than ½$B_{35\%}$ (7,341 t), and mean biomass projected for 2013 (17,106 t) is greater than $B_{35\%}$ (14,681 t). Under scenario 7, mean biomass projected for 2015 (16,835 t) is also greater than $B_{35\%}$. These projections indicate that GOA thornyheads are not currently below MSST, and are not expected to approach MSST status in the next two years.

Other considerations

Currently thornyheads are managed for the entire Gulf of Alaska. Based on the 2003 survey estimates we computed the following apportionment of shortspine thornyhead ABC by management areas and compare the observed proportions from past years survey estimates:

Biomass (tons)					
	Year	**Western**	**Central**	**Eastern**	**Total**
	1990	1,679	5,941	11,997	19,617
	1993	3,706	12,509	16,808	33,023
	1996	8,043	18,741	24,912	51,696
	1999	14,090	32,593	30,671	77,353
	2003	20,922	53,250	27,404	101,576

Proportion		**Western**	**Central**	**Eastern**
	1990	9%	30%	61%
	1993	11%	38%	51%
	1996	16%	36%	48%
	1999	18%	42%	40%
	2003	21%	52%	27%

	Western	**Central**	**Eastern**	**Total**
	21%	52%	27%	
ABC	607	1,544	795	**2,945**

Because the 2001 trawl survey was spatially incomplete (only the shallower regions of the western and central Gulf of Alaska were covered) we omitted these data from consideration for spatial allocation.

Historical removals by foreign vessels appear to have been more concentrated in the central region (Ianelli and Ito, 1995). Since this pattern may reflect current trends, we recommend that management of thornyheads be broken into these regions rather than Gulf-wide. Presently it is impossible to determine the relative magnitude of thornyhead removals in these areas since observer coverage is not evenly distributed. Further considerations on future harvest levels must also account for the impact of trawl closure areas in the eastern portion of the GOA. The impact of this closure will likely shift the relative proportion caught by gear type, but since this will increase the proportion caught by longline gear, the harvest levels recommended here are likely to be more conservative than if the pressumed shift in catch by gear type was accepted.

Summary

The management parameters of interest derived from this assessment are presented in Table 12.13. Please note, however, that management actions should be based on a more complete evaluation of the alternatives presented above rather than the single values given here.

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Tables

Table 12.1. Estimated shortspine thornyhead retained catch and discard levels by gear type[1].

	Trawl			Hook and Line			All Gears Combined		
Year	Retained	Discarded	Total	Retained	Discarded	Total	Retained	Discarded	Total
1967	7	-	7	0	-	0	7	-	7
1968	56	-	56	6	-	6	*62*	-	62
1969	94	-	94	3	-	3	97	-	97
1970	48	-	48	6	-	6	53	-	53
1971	230	-	230	11	-	11	241	-	241
1972	202	-	202	14	-	14	216	-	216
1973	1,550	-	1,550	15	-	15	1,565	-	1,565
1974	1,529	-	1,529	8	-	8	1,537	-	1,537
1975	1,215	-	1,215	15	-	*15*	1,229	-	1,229
1976	1,189	-	1,189	124	-	124	1,313	-	1,313
1977	1,163	-	1,163	234	-	234	1,397	-	1,397
1978	442	-	442	344	-	344	786	-	786
1979	645	-	645	454	-	454	1,098	-	1,098
1980	1,158	-	1,158	327	-	327	1,485	-	1,485
1981	1,139	-	1,139	201	-	201	1,340	-	1,340
1982	669	-	669	118	-	118	787	-	787
1983	620	-	620	109	-	109	729	-	729
1984	177	-	177	31	-	31	208	-	208
1985	70	-	70	12	-	12	82	-	82
1986	607	-	607	107	-	107	714	-	714
1987	1,863	-	1,863	14	-	14	1,877	-	1,877
1988	2,132	-	2,132	49	-	49	2,181	-	2,181
1989	2,547	-	2,547	69	-	69	2,616	-	2,616
1990	1,233	38	1,271	284	20	304	1,518	58	1,576
1991	1,188	60	1,248	236	53	289	1,424	113	1,537
1992	1,041	129	1,169	532	375	907	1,573	504	2,077
1993	489	173	662	401	305	706	890	479	1,369
1994	488	222	710	305	295	600	793	516	1,.310
1995	471	165	636	392	86	478	863	251	1,114
1996	435	170	605	424	101	525	860	272	1,131
1997	567	224	791	398	61	459	964	285	1,249
1998	470	113	583	508	57	565	978	171	1,148
1999	597	195	792	445	43	488	1,042	240	1,282
2000	557	92	649	580	78	658	1,137	170	1,308
2001	479	52	532	770	38	808	1,249	90	1,339
2002	500	90	590	501	47	548	1,001	137	1,138
2003*			604			563			1,167

[1] Prior to 1990 retained catch was assumed to equal retained and discard catch combined. Catches by gear type from 1981-1986 were estimated by apportioning 85% of the total catch to trawl and and 15% to longline gear. ***Source***: 1967-1980 based on estimates extracted from NMFS observer reports (e.g., Wall et al. l978) 1981-1989 based on PACFIN and NMFS observer data, 1990-2001 based on blended NMFS observer data and weekly processor reports. *The 2003 catch was projected from October 2002 NMFS reports.

Table 12.2. Research catches of shortspine thornyhead in the GOA, 1977-2003 in tons.

Year	Domestic Longline Survey Catch	Research catch trawl	Research catch Co-op longline	Total research catch
1977		0.77		0.8
1978		1.20		1.2
1979		4.54	2.93	7.5
1980		1.42	4.98	6.4
1981		9.51	4.64	14.2
1982		5.58	4.11	9.7
1983		0.72	4.22	5.0
1984		23.89	3.10	27.0
1985		12.03	3.51	15.5
1986		1.75	3.50	5.3
1987		16.78	3.54	20.3
1988	1.95	0.04	4.73	6.7
1989	3.44	0.15	4.51	8.1
1990	3.32	3.59	3.64	10.6
1991	3.80		3.38	7.2
1992	5.40		3.72	9.1
1993	4.66	5.49	4.01	14.2
1994	4.41		4.77	9.2
1995	5.42			5.4
1996	6.18	6.05		12.2
1997	5.89			5.9
1998	5.70	9.36		15.1
1999	5.74	23.09		28.8
2000	5.19			5.2
2001	6.72	2.22		8.9
2002	5.43			5.4
2003				

Table 12.3. Relative population number (RPN) and weight (RPW) from the domestic longline survey 1990-2003 (Mike Sigler and Chris Lunsford, NMFS Auke Bay Lab, pers. comm.). Note that the RPN data were used to tune the model.

Domestic survey

Year	RPN	RPW
1990	43,479	20,667
1991	56,615	23,324
1992	73,233	32,068
1993	66,166	28,448
1994	49,191	25,294
1995	58,553	26,323
1996	66,392	32,217
1997	62,529	29,420
1998	60,740	31,045
1999	67,901	33,810
2000	59,058	28,657
2001	86,970	43,719
2002	76,996	38,004
2003	71,966	34,239

Table 12.4. Data types used in the model for shortspine thornyheads in the GOA.

Data Component	Years of data
Trawl survey size composition and biomass estimates	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003
Longline survey relative abundance and size composition	1990-2003
Trawl fishery size composition data	1976-77, 1982-84, 1990-96, 1998-2003
Longline fishery size composition data	1977-81, 1991-95, 1998, 2000-2003
Trawl fishery harvests	1967-2003
Longline fishery harvests	1967-2003

Table 12.5. Model equations describing population dynamics.

Equations	Description
$N_{t,1} = R_t = R_0 e^{\tau_t}$, $\tau_t \sim \mathrm{N}\left(0,\sigma_R^2\right)$	Recruitment
$C_{i,t,a} = \frac{F_{i,t,a}}{Z_{t,a}}\left(1-e^{-Z_{t,a}}\right) \quad N_{t,a} \quad 1 \le t \le T \quad 1 \le a \le A$	Catch gear type *i*, year *t*, age class *a* Numbers
$N_{t+1,a+1} = N_{t,a} e^{-Z_{t,a}} \quad 1 < t \le T \quad 1 \le a < A$	
$S_t = \sum_{a=5}^{54+} w_{t,a}\phi_a N_{t,a}$	Spawning biomass in year *t*
$N_{t+1,A} = N_{t,A-1}e^{-Z_{t,A-1}} + N_{t,A}e^{-Z_{t,A}} \quad 1 \le t \le T$	Numbers in “plus” group”
$Z_{t,a} = \sum_i F_{i,t,a} + M$	Total Mortality
$F_{i,t,a} = s_{i,a}\mu_i^F \exp\left(\varepsilon_{i,t}\right) \quad \varepsilon_{i,t} \sim N\left(0,\sigma_i^2\right)$	Components of fishing mortality
$s_{i,a} = \exp\left(\eta_{i,a}\right) \quad \eta_{i,a} \sim N\left(0,\sigma_{s_{i,a}}^2\right)$	Age-effect of fishing
$C_{t\cdot}^i = \sum_{a=1}^{A} C_{t,a}^i$	Total catch for fishery *i.*
$p_{t,a}^i = \frac{C_{t,a}^i}{C_{t\cdot}^i}$	Proportion at age in catch
$\hat{Y}_t^i = \sum_{a=1}^{A} w_{t,a} C_{t,a}^i$	Yield in year *t* for fishery *i.*
X	Transition matrix dimensioned by 50 ages by 25 length bins (*L*), parameterized by growth relationship shown in Figure 7.
$\hat{g}_t^i = p_t^i \cdot X,\ \hat{g}_{t,l}^i,\ l = 1,2,3 \ldots L$	Proportion at length in vector $\hat{g}_t^i$ for fishery or survey *i* in year *t*.

Table 12.6. List of variables and their definitions used in this model.

Variable	Definition
R_t	age 1 recruitment in year t
R_0	geometric mean value of age 1 recruitment, 1967-2002
$R_0^{'}$	geometric mean value of age 1 recruitment prior to 1967 (establishes initial age composition)
τ_t	recruitment deviation in year t
T	number of years of fishing (i.e., t=1 corresponds to 1967, and t=T corresponds to 2002)
A	number of age classes in the population model (A=50 ranging from a=1 that corresponds to age 5 and a=50 corresponds to fish age 54 and older,
$N_{t,a}$	number of fish age a in year t,
$C_{t,a}$	catch number of age group a in year t,
$P_{t,a}$	proportion of the total catch in year t, that is in age group a,
$C_{t\cdot}$	total catch in year t,
$W_{t,a}$	mean body weight (kg) of fish in age group a in year t,
θ_a	proportion mature at age a, $\theta_a = \frac{1}{1+e^{-(\rho a-\beta)}}$
Y_t^i, $\hat{Y}_t^i$	total yield weight in year t, fishery i, observed and estimated.
$F_{i,t,a}$	instantantaneous fishing mortality for gear type i, age group a, in year t,
M	instantantaneous natural mortality (assumed constant for all ages and years,
$Z_{t,a}$	instantantaneous total mortality for age group a, in year t,
$S_{i,a}$	age-effect of fishing for age group a in gear type i, normalized to average 1.0 over ages a=1 to A,
μ_i^F	median year-effect of fishing mortality,
$\varepsilon_{i,t}$	the residual year-effect of fishing mortality (note that effective effort fluctuates in fidelity to the total catch each year).

Table 12.7. Statistical formulae for the likelihood components.

Equations	Description
$L_1 = \sum_f \sum_t n_t^f \sum_{l=1}^{L} \ln\left(\hat{g}_{t,l}^f\right) f$	Multinomial –log likelihood value for f observation types (fisheries and surveys)
$L_2 = \sum_i \sum_{t_i} \frac{\ln\left(I_{t_i}^i / \hat{I}_{t_i}^i\right)^2}{2\left(\sigma_{t_i}^i\right)^2}$	Likelihood component for indices *ith* abundance index (i.e., bottom trawl and longline surveys)
$L_3 = \lambda_1 \sum_{i,t} \varepsilon_{i,t}^2$	Fishing mortality term for each i fishery (provides regularity,
$L_4 = \lambda_2 \sum_{i,t} \left(Y_t^i - \hat{Y}_t^i\right)^2$	Catch biomass component
$L_5 = \lambda_3 \ln\left(\hat{M}/M_{prior}\right)^2 + \lambda_4 \ln\left(\hat{q}/q_{prior}\right)^2$	Prior components on natural mortality, and survey catchability.
$L_6 = \sum_{i,a} \frac{\left(\eta_{i,a}\right)^2}{2\sigma_{s_{i,a}}^2}$	Component constraining age-age variability in selectivity for each i gear type.
$L_{tot} = \sum_{i=1}^{6} L_i$	Total – log likelihood (or posterior pdf)

Table 12.8. Alternative model results for shortspine thornyheads in the Gulf of Alaska; effective sample size, likelihood components, estimates of biomass (current, B40% and pristine), recruitment, yield, and fishing mortality rates. See text for model descriptions.

Description	**Base model**	**FixM 0.038**	**FixM 0.038 Sel**	**RadioAge Length**	**M prior 0.01**	**M prior 0.03**	**M prior 0.08**	**M prior 0.10**
Effective N								
Trawl Fishery	184	84	66	57	65	139	203	202
Longline Fishery	61	40	40	33	33	55	63	63
Trawl survey	416	376	288	88	397	387	416	405
Longline survey	361	104	97	80	70	220	524	578
Likelihoods								
Surveys								
Trawl Survey	47.1	51.4	56.7	69.2	52.8	49.2	44.4	43.0
Longline Survey	8.1	6.5	5.6	15.4	6.0	7.6	8.4	8.5
Priors								
Prior on M	24.8	0.0	0.0	10.5	66.2	61.4	3.3	0.0
Recruitment Likelihood	20.5	62.1	99.2	16.5	97.1	28.2	19.3	19.8
Trawl Fishery Size comp	65.8	88.6	100.0	76.1	99.7	72.6	62.3	61.5
Longline Fishery Size comp	93.0	98.2	98.9	187.1	104.3	93.0	94.6	95.6
Trawl Survey Size comp	20.1	23.2	38.3	45.1	25.4	20.9	19.8	19.8
Longline Survey Size comp	24.0	51.2	53.3	232.6	69.8	30.3	21.9	21.7
Trawl Fishery selectivity	1.9	2.9	1.1	1.0	3.9	2.0	1.6	1.5
Longline Fishery selectivity	1.2	6.0	1.8	2.9	10.4	1.9	0.9	0.9
Trawl Survey selectivity	4.7	9.1	12.0	14.3	10.6	6.6	3.1	2.5
Longline Survey selectivity	3.2	19.3	4.1	7.0	31.2	6.8	1.6	1.2
Catch likelihood	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
N parameters	292	291	291	292	292	292	292	292
Total Likelihood	314.5	418.6	471.2	677.8	577.4	380.7	281.4	276.2
Biomass								
2004 Biomass	59,661	93,522	79,683	67,547	133,720	63,561	62,950	65,936
(cv)	6%	6%	5%	5%	9%	6%	8%	8%
$B_{40\%}$	37,475	82,107	75,817	39,742	151,930	44,820	35,335	35,212
(cv)	10%	6%	6%	10%	7%	9%	11%	11%
B0	94,741	205,530	189,760	99,502	379,970	112,650	90,012	89,883
(cv)	10%	6%	6%	10%	7%	9%	11%	11%
2004 Biomass / $B_{40\%}$	159%	114%	105%	170%	88%	142%	178%	187%
2004 Biomass / B0	63%	46%	42%	68%	35%	56%	70%	73%
Avg age 5 rec (all years)	25,101	11,054	10,553	19,078	8,576	18,078	33,969	38,798
Avg age 5 rec (since 1977)	27,872	11,664	10,796	18,971	8,806	19,703	38,444	44,278
Natural Mortality	0.082	0.038	0.038	0.036	0.023	0.066	0.096	0.102
Yield								
2004 Yield $F_{40\%}$	2,945	2,208	2,024	1,869	2,137	2,454	3,803	4,330
2004 Yield $F_{35\%}$	3,510	2,590	2,395	2,243	2,499	2,923	4,403	4,914
Full selection F's								
Trawl $F_{40\%}$	0.040	0.020	0.015	0.020	0.017	0.028	0.052	0.057
Longline $F_{40\%}$	0.045	0.018	0.015	0.021	0.013	0.030	0.071	0.085
$F_{40\%}$ Combined	0.085	0.037	0.030	0.041	0.030	0.059	0.122	0.143
Trawl $F_{35\%}$	0.048	0.023	0.018	0.024	0.019	0.034	0.060	0.065
Longline $F_{35\%}$	0.055	0.021	0.018	0.026	0.015	0.036	0.083	0.099
$F_{35\%}$ Combined	0.102	0.044	0.036	0.050	0.035	0.070	0.143	0.163

Table 12.9. Estimates of beginning of year 5+ biomass, female spawning biomass, and recruitment for shortspine thornyheads in the Gulf of Alaska, base model.

Year	Total age 5+ Biomass	Female Spawning Biomass	Age 5 Recruitment
1967	64,128	29,134	20,219
1968	64,322	29,195	20,205
1969	64,486	29,246	20,714
1970	64,657	29,297	21,573
1971	64,910	29,385	22,215
1972	64,991	29,393	22,135
1973	65,121	29,428	22,128
1974	63,894	28,805	22,642
1975	62,748	28,216	22,913
1976	61,952	27,802	22,465
1977	61,009	27,362	18,943
1978	59,998	26,899	18,773
1979	59,661	26,759	19,331
1980	59,052	26,480	20,373
1981	58,085	26,021	20,937
1982	57,290	25,643	20,695
1983	57,124	25,550	21,786
1984	57,073	25,494	22,851
1985	57,783	25,711	29,539
1986	58,601	26,006	26,867
1987	58,780	26,000	25,946
1988	58,109	25,451	36,926
1989	57,325	24,804	39,974
1990	56,433	24,008	47,270
1991	56,287	23,783	29,704
1992	56,367	23,655	33,465
1993	55,851	23,344	28,671
1994	56,049	23,456	26,119
1995	56,432	23,660	29,106
1996	56,932	24,002	24,773
1997	57,400	24,356	23,981
1998	57,746	24,664	24,170
1999	58,347	25,011	29,560
2000	58,667	25,291	24,088
2001	58,932	25,519	23,663
2002	59,084	25,709	21,534
2003	59,661	25,975	22,498

Table 12.10. Reference fishing mortality rates (coefficient of variation in parenthesis), and yield for 2004 with upper and lower 25 percentiles for ABC and OFL computations, base model. Fishing mortality rates expressed as full selection values.

	Longline	Trawl	Combined
$F_{40\%}$	0.045	0.040	0.085
	(13%)	(9%)	
$F_{35\%}$	0.055	0.048	0.102
	(13%)	(9%)	
	25%	**50%**	**75%**
ABC	2,759	**2,945**	3,144
OFL	3,295	3,510	3,739

*Assuming relative catch in 2003 is the same between the gear types.

Table 12.11. Base Model estimates of the trend in average (ages 5-54) and full selection fishing mortality rates by gear type and combined for shortspine thornyheads in the Gulf of Alaska.

	Average F			Full selection F		
Year	**Trawl**	**Longline**	**Combined**	**Trawl**	**Longline**	**Combined**
1967	0.000	0.000	0.000	0.000	0.000	0.000
1968	0.001	0.000	0.001	0.001	0.000	0.002
1969	0.001	0.000	0.001	0.002	0.000	0.002
1970	0.001	0.000	0.001	0.001	0.000	0.001
1971	0.004	0.000	0.004	0.006	0.000	0.006
1972	0.003	0.000	0.003	0.005	0.000	0.005
1973	0.024	0.000	0.024	0.040	0.000	0.040
1974	0.024	0.000	0.025	0.040	0.000	0.041
1975	0.020	0.000	0.020	0.033	0.000	0.033
1976	0.020	0.002	0.022	0.032	0.003	0.035
1977	0.019	0.004	0.024	0.032	0.006	0.038
1978	0.007	0.006	0.014	0.012	0.009	0.021
1979	0.011	0.008	0.019	0.018	0.012	0.030
1980	0.020	0.006	0.026	0.033	0.009	0.041
1981	0.020	0.004	0.024	0.033	0.005	0.038
1982	0.012	0.002	0.014	0.019	0.003	0.022
1983	0.011	0.002	0.013	0.018	0.003	0.021
1984	0.003	0.001	0.004	0.005	0.001	0.006
1985	0.001	0.000	0.001	0.002	0.000	0.002
1986	0.010	0.002	0.012	0.017	0.003	0.020
1987	0.032	0.000	0.032	0.053	0.000	0.053
1988	0.037	0.001	0.038	0.062	0.001	0.063
1989	0.046	0.001	0.047	0.076	0.002	0.078
1990	0.023	0.006	0.030	0.039	0.009	0.048
1991	0.023	0.006	0.029	0.038	0.009	0.047
1992	0.022	0.020	0.042	0.036	0.029	0.065
1993	0.013	0.016	0.029	0.021	0.023	0.044
1994	0.014	0.014	0.027	0.022	0.020	0.042
1995	0.012	0.011	0.023	0.020	0.016	0.036
1996	0.011	0.012	0.024	0.019	0.018	0.036
1997	0.014	0.011	0.025	0.024	0.016	0.040
1998	0.010	0.013	0.024	0.017	0.019	0.037
1999	0.014	0.012	0.025	0.023	0.017	0.040
2000	0.011	0.015	0.027	0.019	0.022	0.041
2001	0.009	0.019	0.028	0.015	0.027	0.042
2002	0.010	0.012	0.022	0.016	0.018	0.034
2003	0.010	0.012	0.022	0.016	0.018	0.034

Table 12.12. Projected biomass and catch under five harvest scenarios.

Reference Points (all biomass estimates refer to female spawners)							
B_0		39,566					
$B_{40\%}$		15,826					
$B_{35\%}$		13,848					
Year		2003	2004	2005	2006	2007	2008
Scenario							
1: Max ABC							
	Mean Biomass	25,260	25,154	24,548	23,935	23,332	22,743
	Stdev Biomass	0.00	4.17	11.21	20.98	36.17	60.12
	Mean Catch	1500	2818	2784	2739	2681	2615
	Stdev Catch	0.00	0.93	1.38	1.81	2.35	3.05
2: 65% max ABC							
	Mean Biomass	25,260	25,278	25,140	24,967	24,776	24,566
	Stdev Biomass	0.00	4.17	11.24	21.06	36.39	60.61
	Mean Catch	1,500	1,851	1,869	1,877	1,875	1,865
	Stdev Catch	0.00	0.61	0.90	1.18	1.53	2.00
3: 50% max ABC							
	Mean Biomass	25,260	25,331	25,398	25,426	25,427	25,402
	Stdev Biomass	0.00	4.17	11.25	21.10	36.48	60.82
	Mean Catch	1,500	1,431	1,457	1,477	1,489	1,493
	Stdev Catch	0.00	0.47	0.69	0.91	1.18	1.54
4: 5 Year average F (=0.03)							
	Mean Biomass	25,260	25,340	25,442	25,504	25,539	25,546
	Stdev Biomass	0.00	4.17	11.25	21.11	36.50	60.86
	Mean Catch	1,500	1,359	1,387	1,408	1,421	1,427
	Stdev Catch	0.00	0.44	0.66	0.86	1.12	1.47
5: No catch							
	Mean Biomass	25,260	25,509	26,283	27,028	27,750	28,442
	Stdev Biomass	0.00	4.17	11.29	21.23	36.80	61.54
	Mean Catch	1,500	0	0	0	0	0
	Stdev Catch	0.00	0.00	0.00	0.00	0.00	0.00

Table 12.13. Summary management values based on this 2002 assessment for shortspine thornyheads in the Gulf of Alaska.

Management Parameter	**Value**
M (natural mortality)	0.082 yr^{-1}
Approximate age at full recruitment	Younger for trawl, older for longline
$F_{35\%}$ (Full selection)	0.102
$F_{40\%}$ (Full selection)	0.085
Unfished female spawning biomass	37,903 t
Long-term $B_{40\%}$ (female spawning biomass)	16,895 t
2003 female spawning biomass	25,975 t
2003 age 5+ biomass	59,661 t
F_{ABC}	0.085
ABC (Reference model)	**2,945 t**
$F_{overfishing}$	0.102
Overfishing level	**3,510 t**

Figures

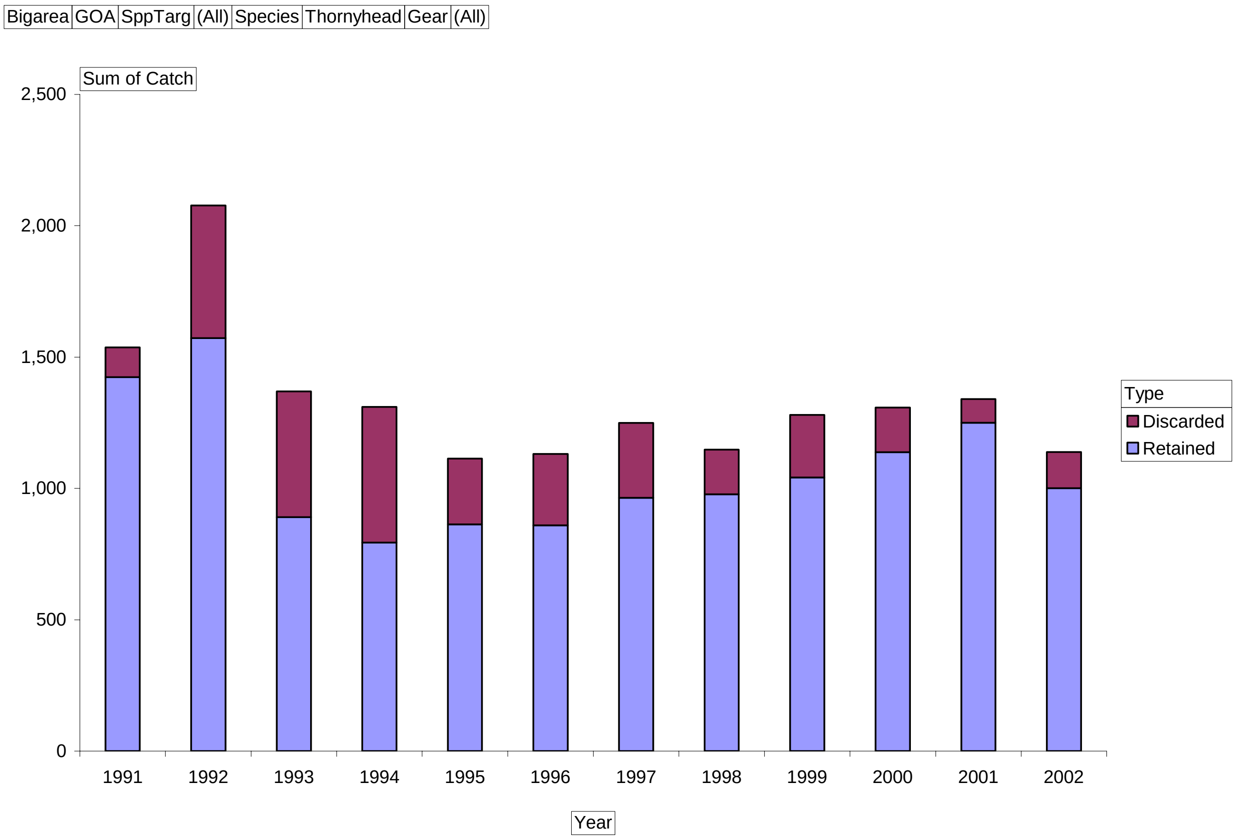


Figure 12.1. Proportion retained and discarded shortspine thornyhead in 1991-2002. *Source: NMFS Alaska Fisheries Science Center and Regional Office blend data.*

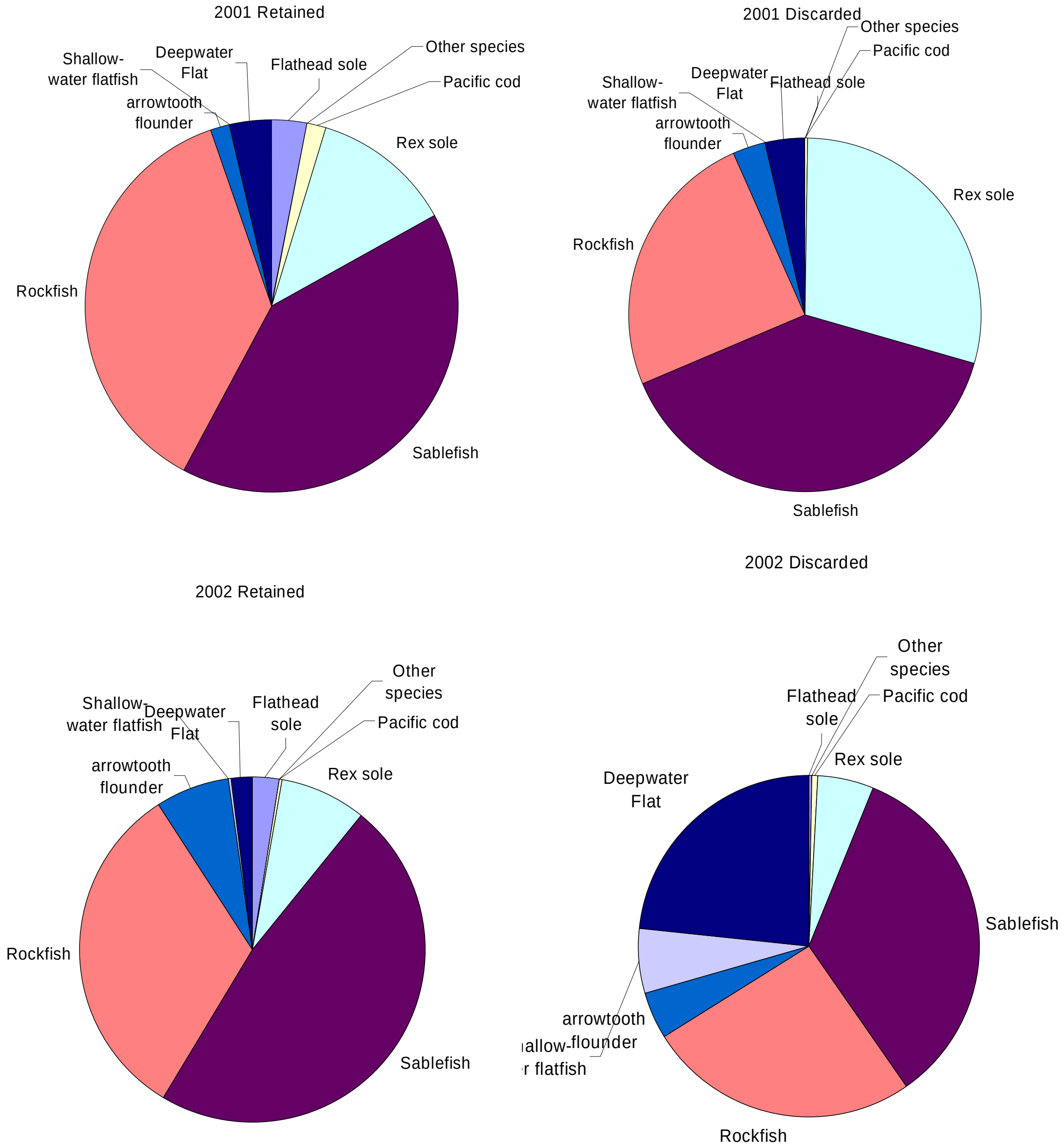


Figure 12.2. Retained versus discarded GOA shortspine thornyhead by directed fishery for 2001 & 2002.

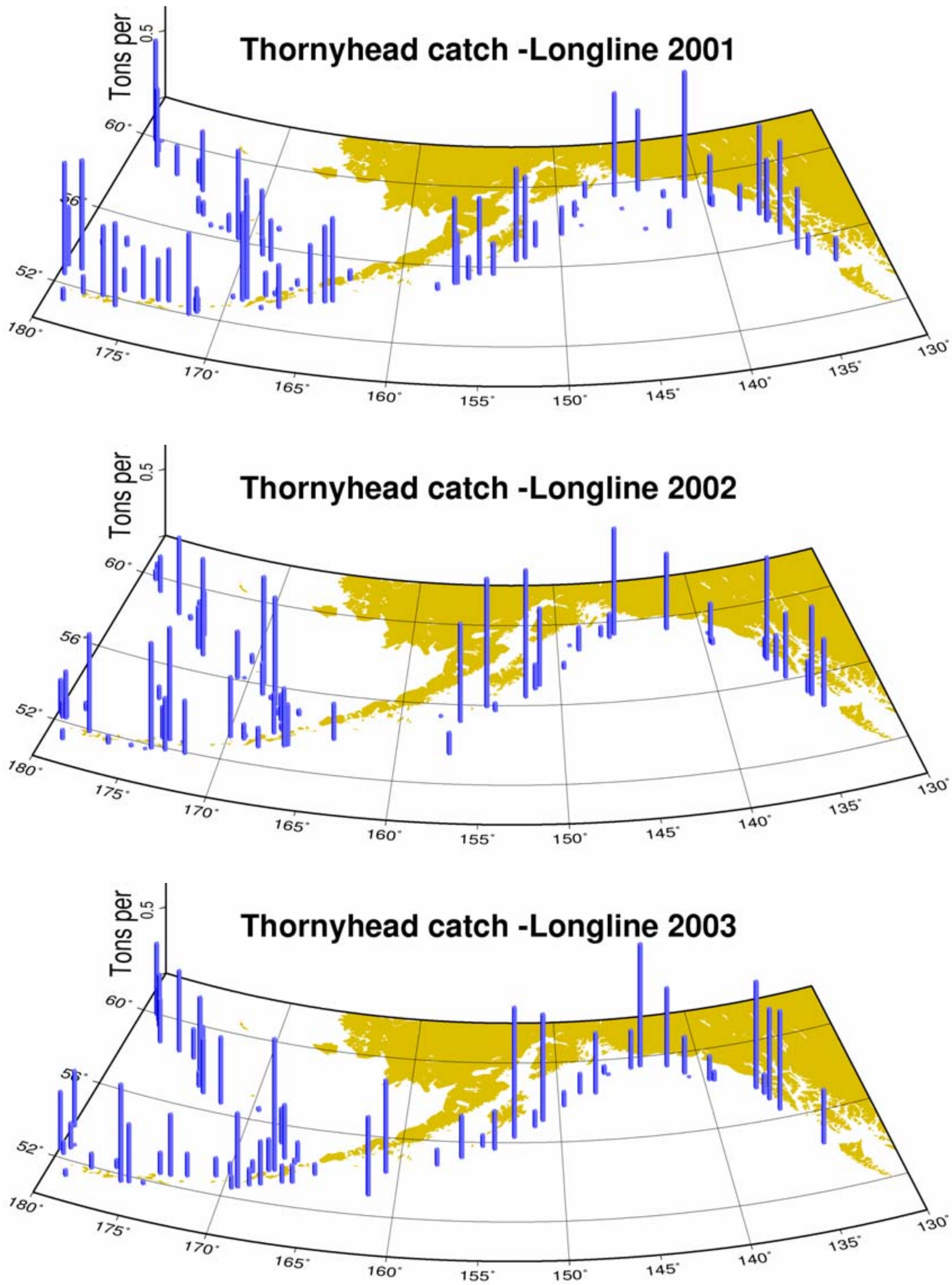


Figure 12.3. Distribution of thornyhead catches by commercial longline gear, aggregated by 1 degree longitude and 0.5 degrees latitude, 2001-2003.

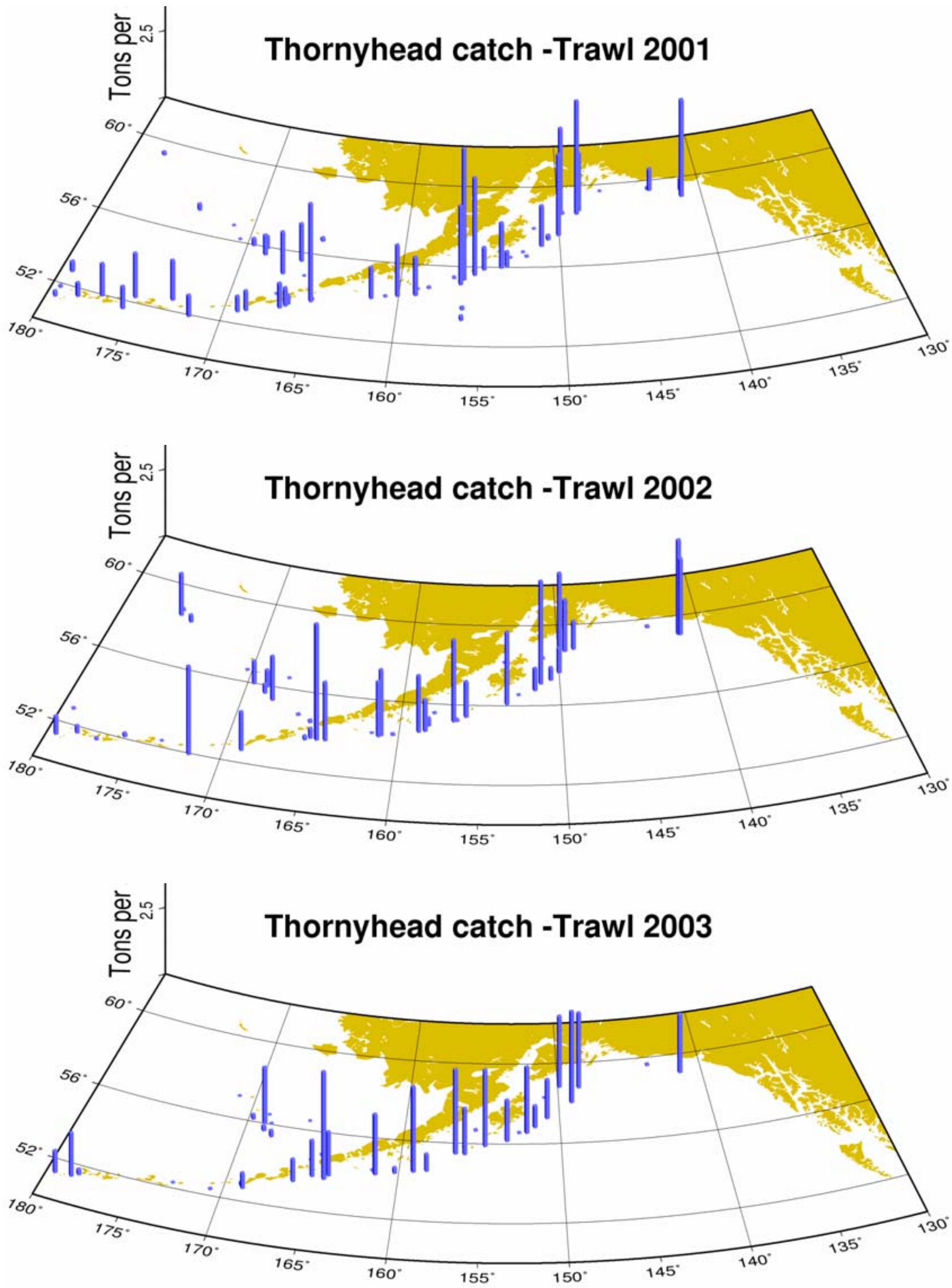


Figure 12.4. Distribution of thornyhead catches by commercial trawl gear aggregated by 1 degree longitude and 0.5 degrees latitude, 2001-2003.

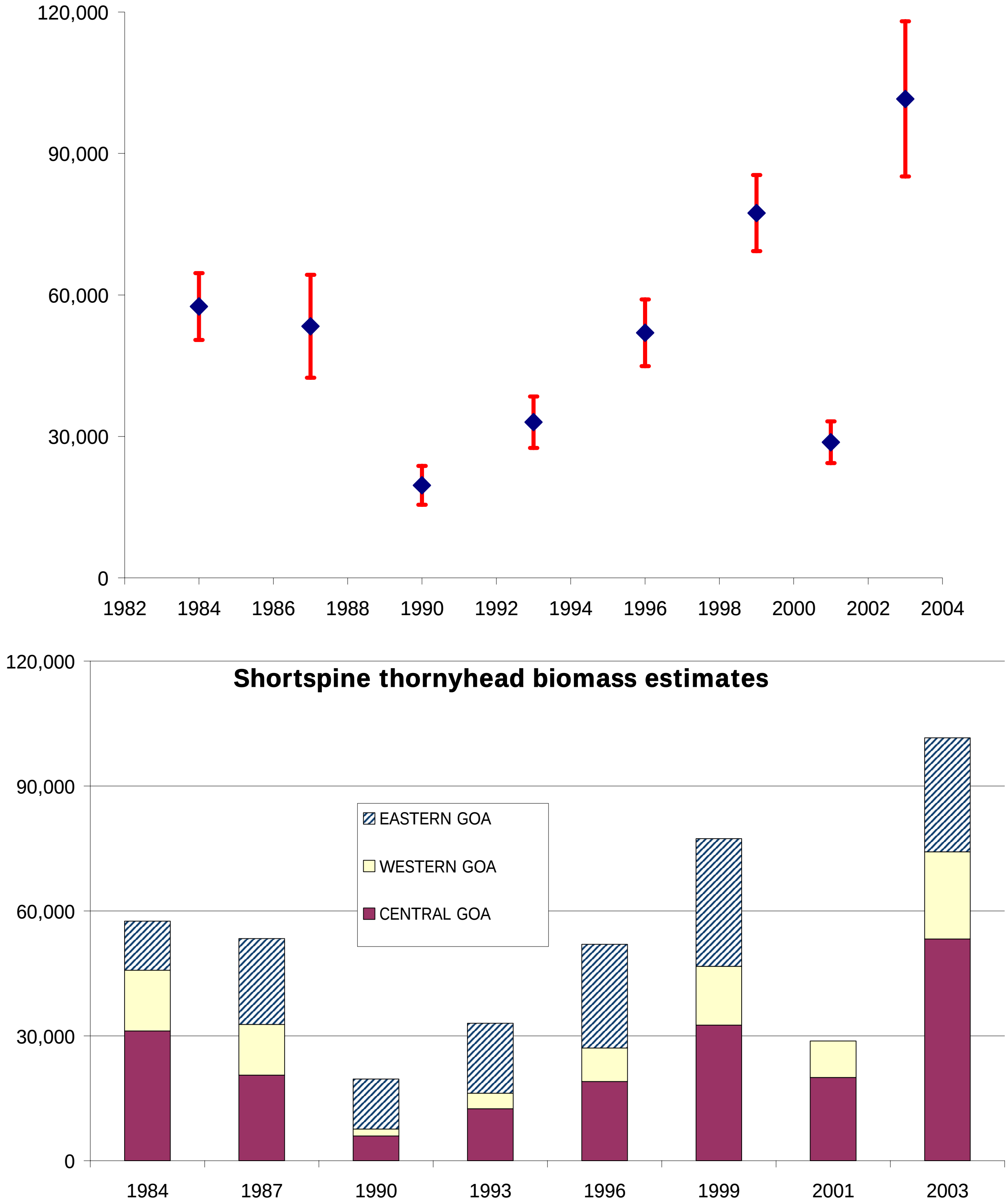


Figure 12.5. Shortspine thornyhead biomass estimates (with standard errors) from the NMFS triennial trawl survey (upper panel). Biomass estimates by region (lower). Note that the 1990, 1993, and 1996 surveys did not extend to deep water (>500m), consequently, a significant proportion of the stock may not have been sampled. In 2001, neither deep water stations nor the eastern Gulf were surveyed; therefore, significant portions of the stock were not sampled.

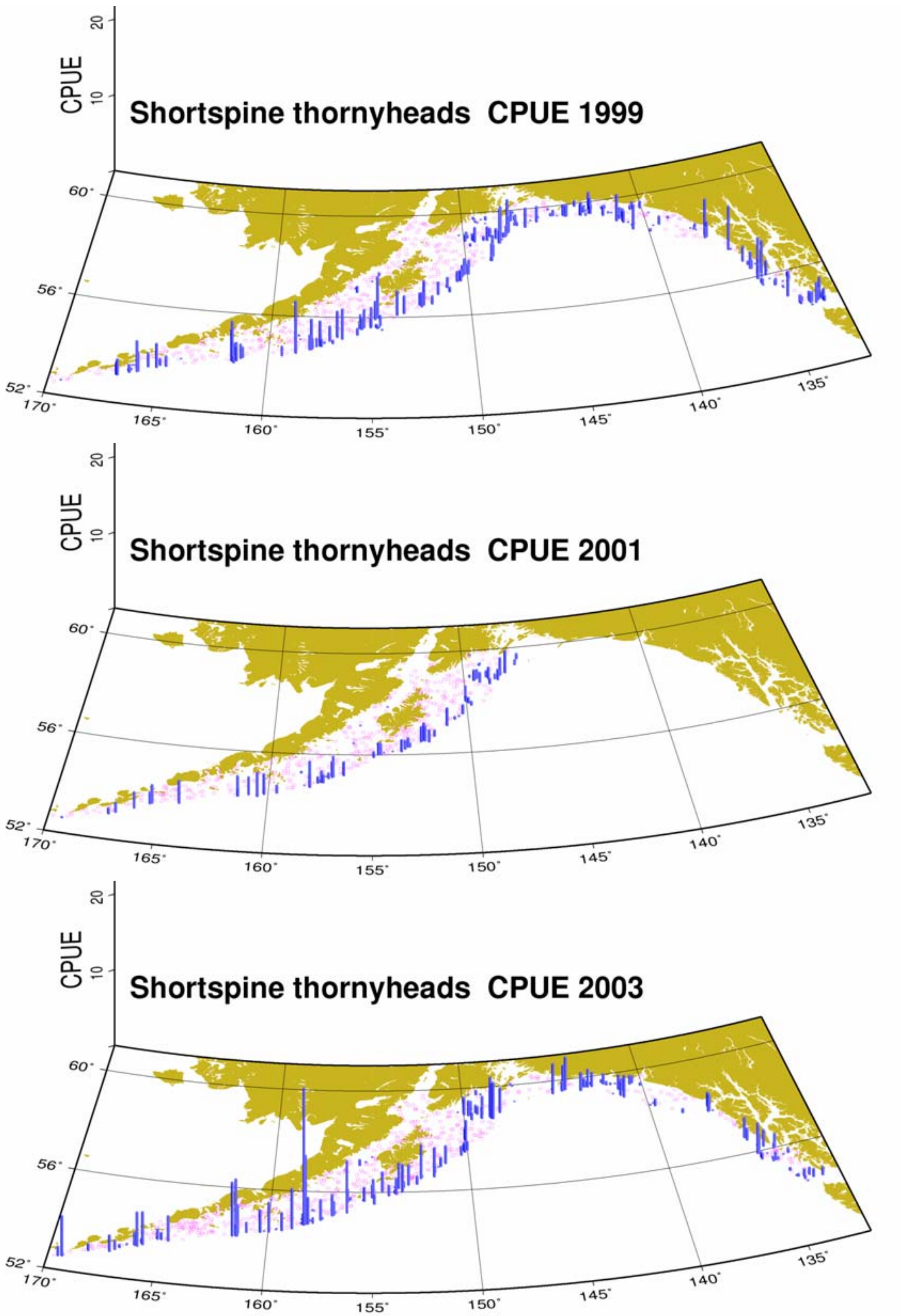
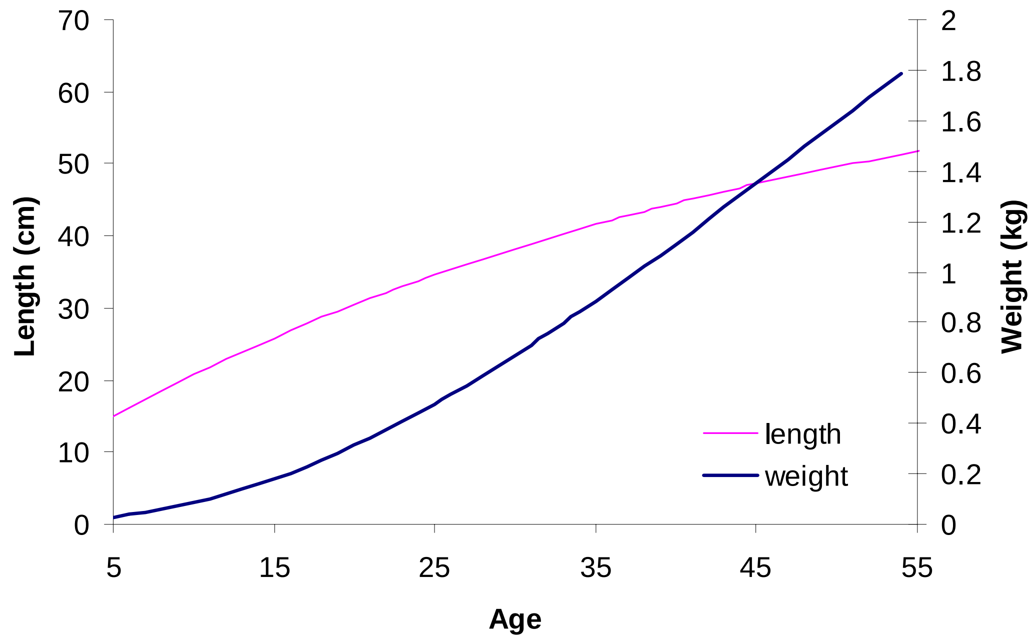


Figure 12.6. Distribution of thornyhead CPUE from recent triennial trawl surveys. Height of vertical bars is proportional to CPUE by weight. Circles represent stations where no shortspine thornyheads were captured.



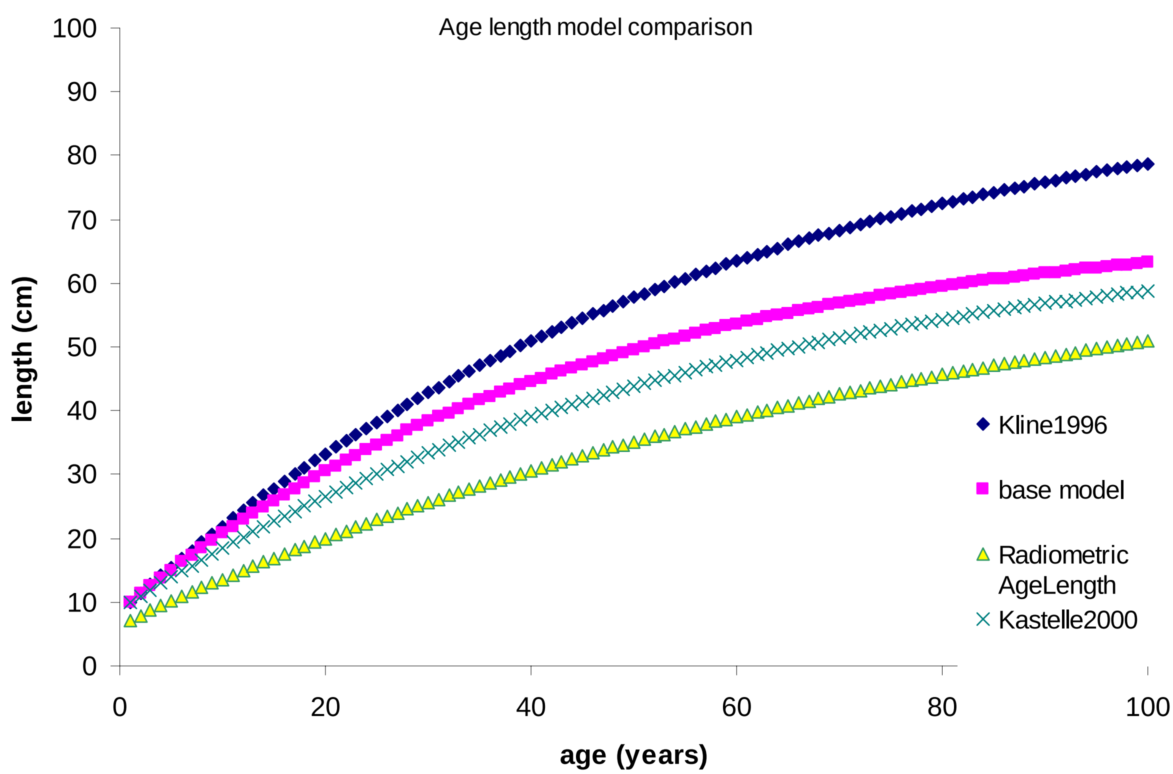


Figure 12.7. Assumed average length and weight at age for Gulf of Alaska shortspine thornyheads (upper panel) and alternative growth models tested (lower panel).

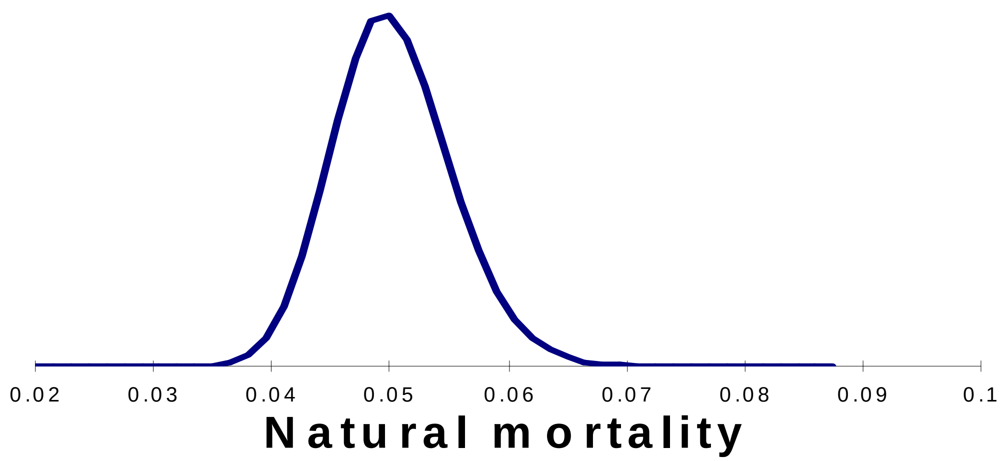


Figure 12.8. Prior distribution assumed for natural mortality of thornyheads (base model and alternative AgeLength models).

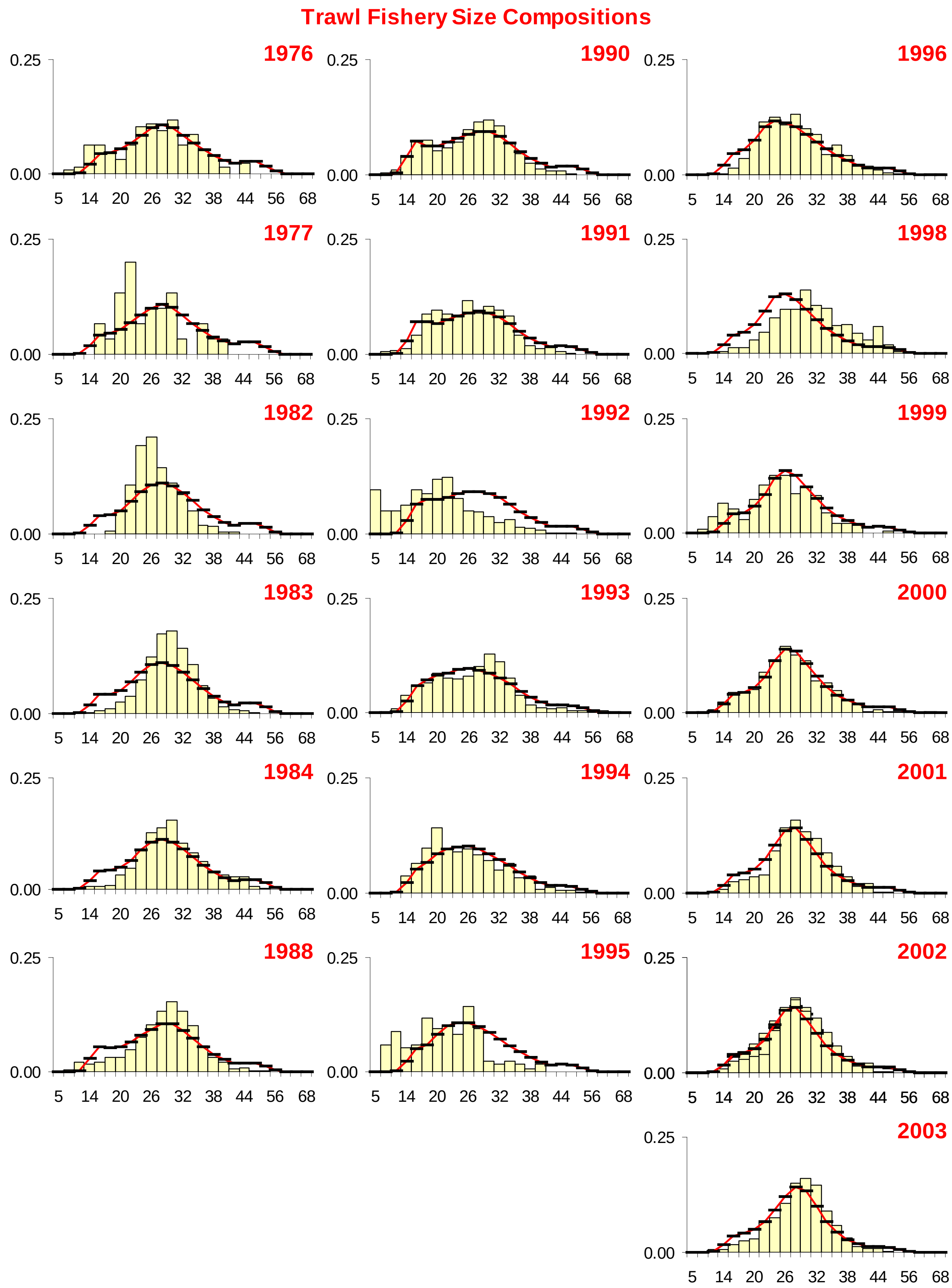


Figure 12.9. Base Model fits to the trawl shortspine thornyheads fishery size composition data.

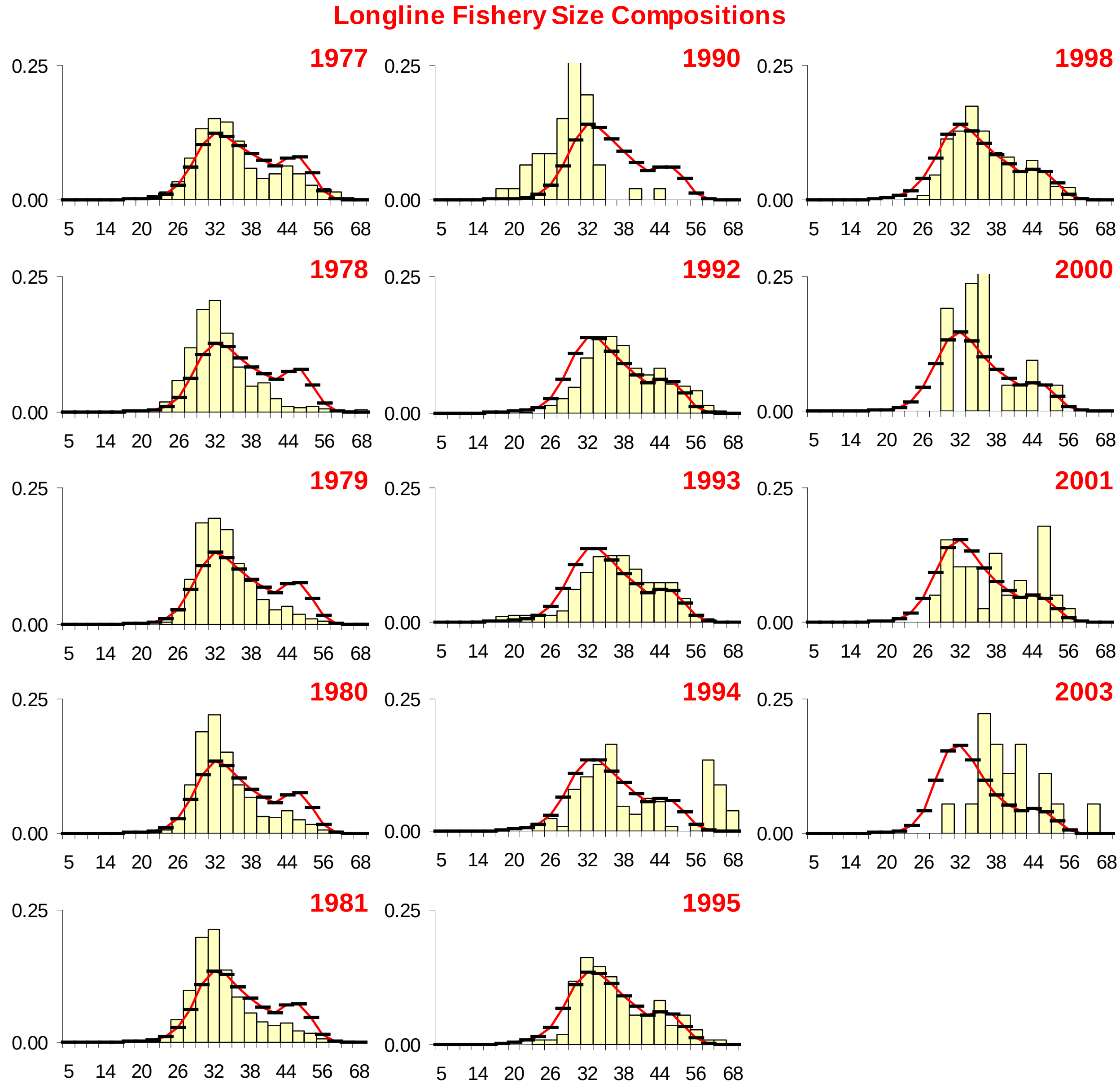


Figure 12.9. (Cont'd) Base Model fits to the longline shortspine thornyheads fishery size composition data.

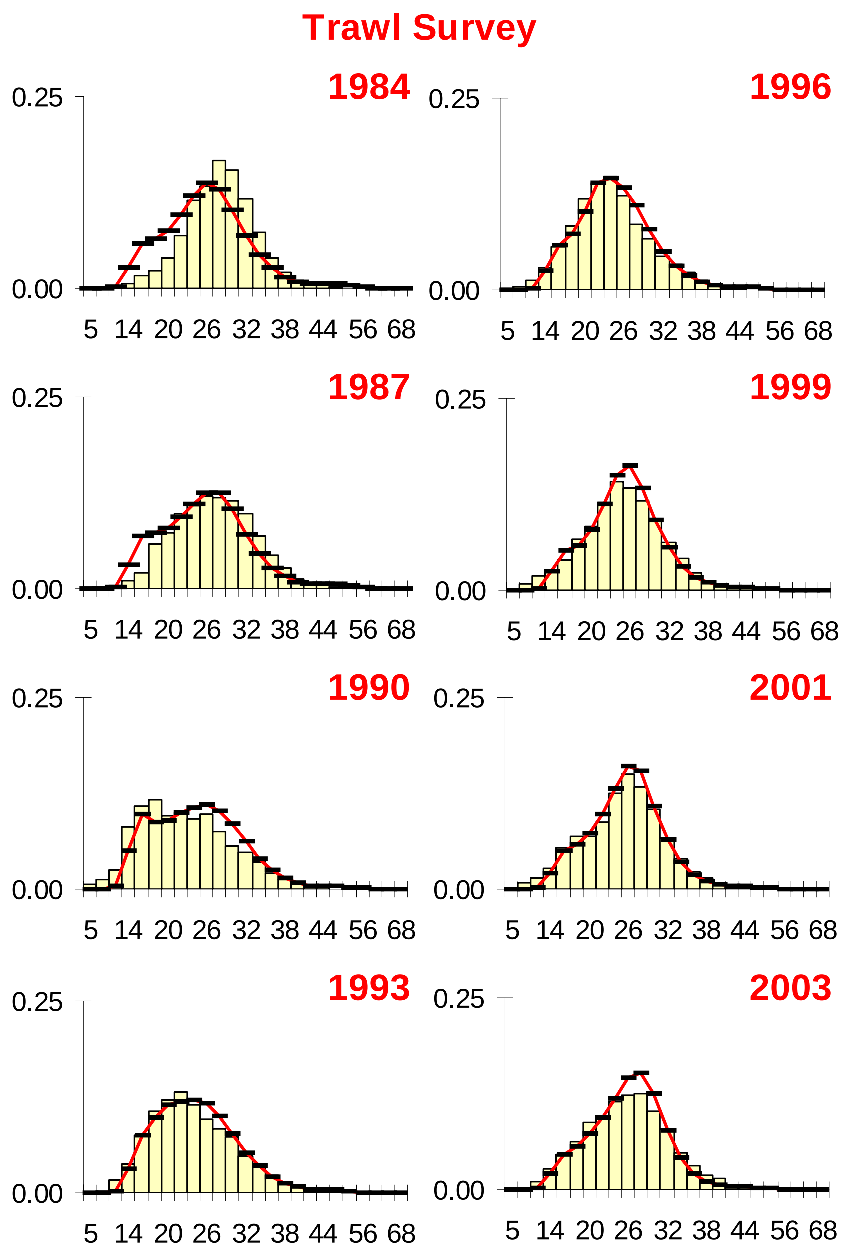


Figure 12.9. (Cont'd) Base Model fits to the trawl survey size composition data.

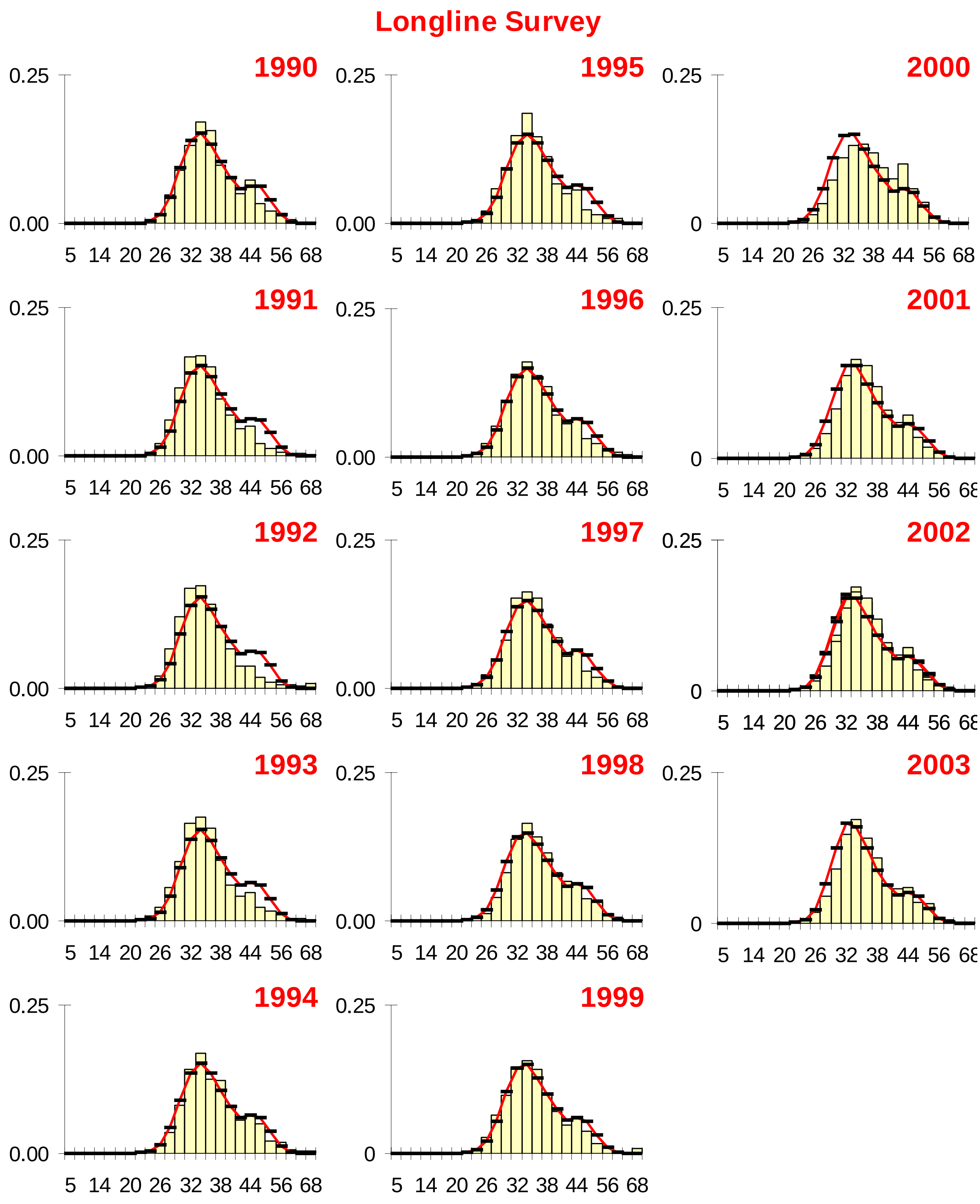


Figure 12.9. (Cont'd) Base Model fits to the longline survey shortspine thornyheads size composition data.

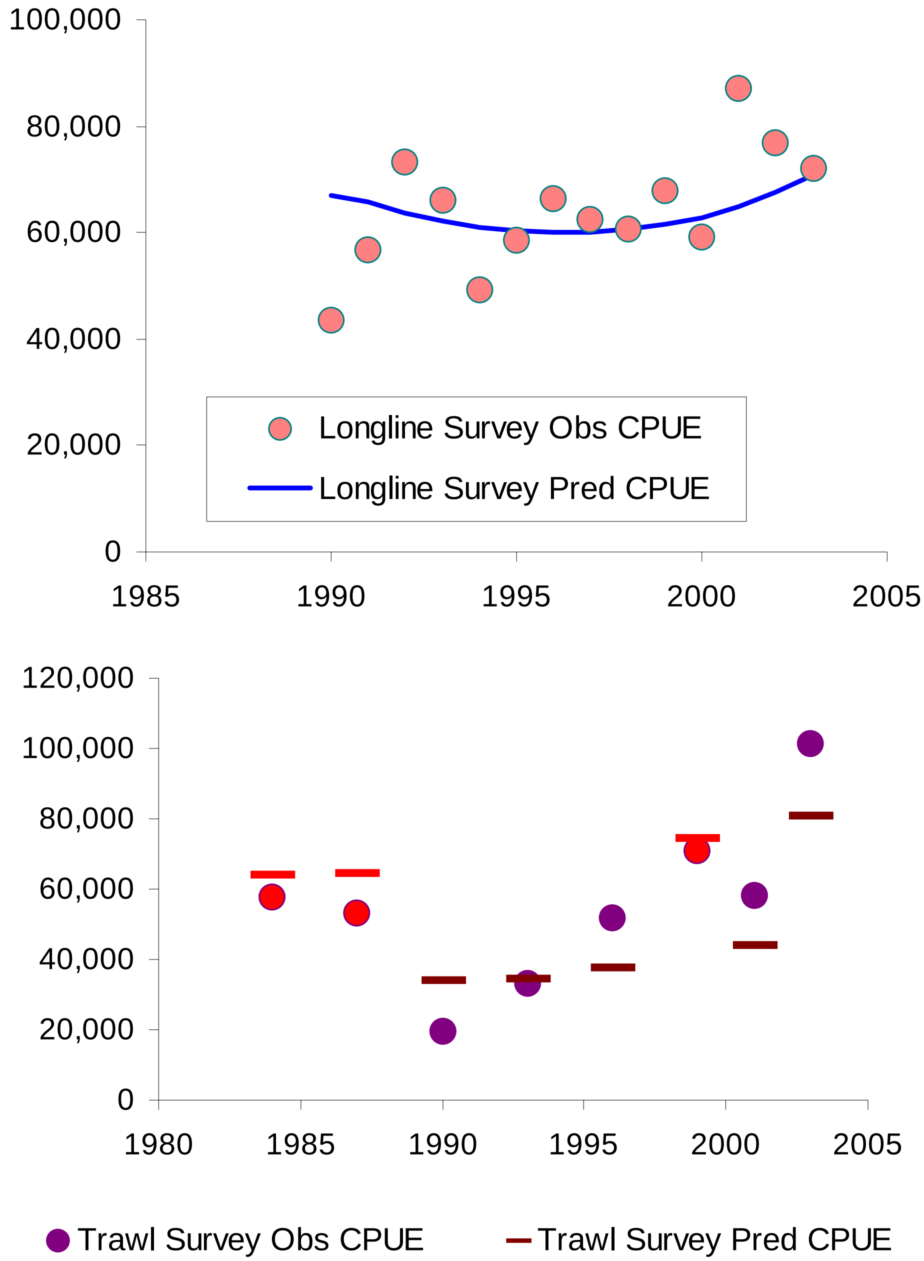


Figure 12.10. Base Model fits to the relative abundance index from the longline surveys (RPN, top panel) and the triennial trawl surveys (bottom panel) for shortspine thornyheads. Note that the triennial survey was modeled with two catchability terms to reflect the change in distribution covered by the survey after 1989.

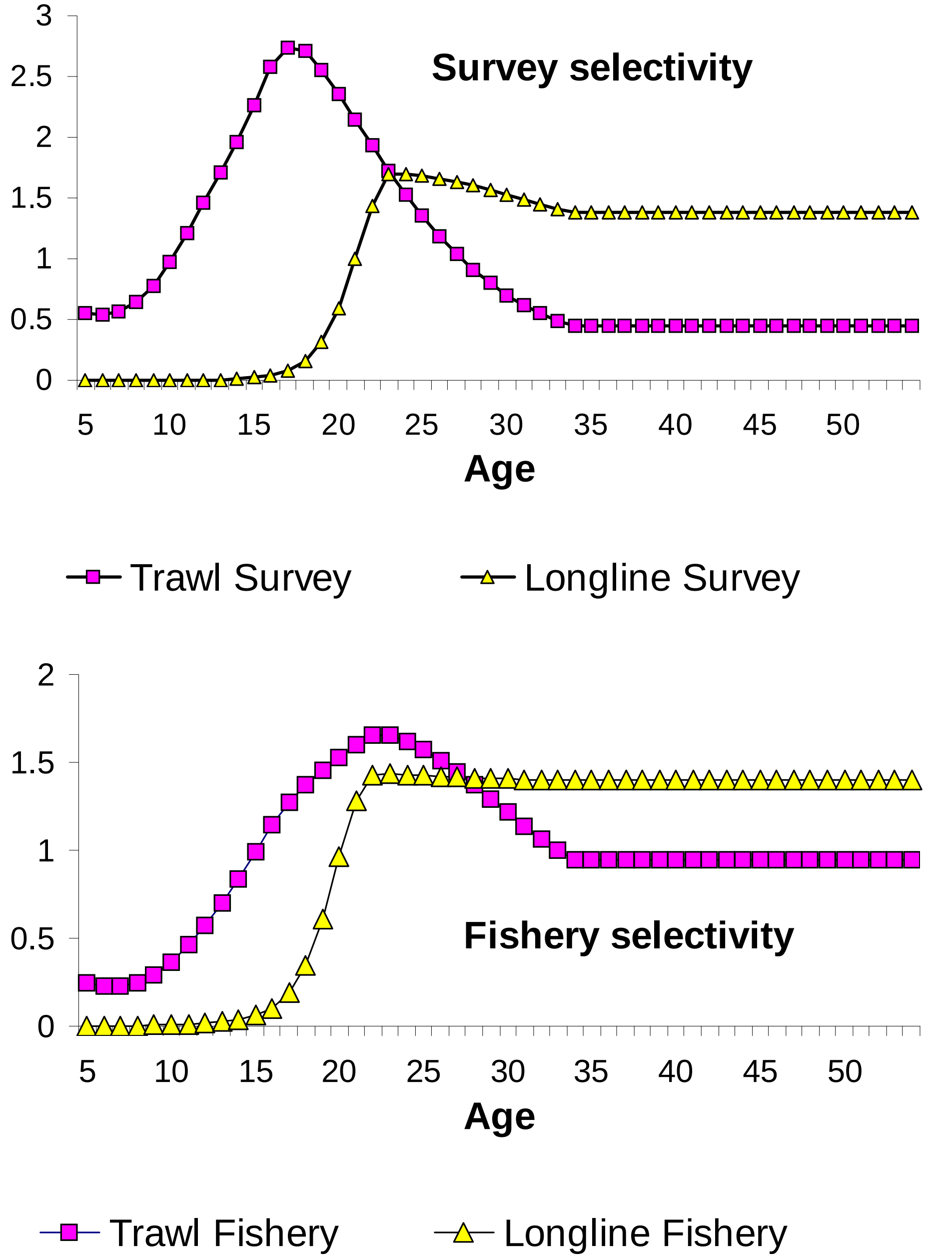


Figure 12.11. Selectivity of shortspine thornyheads estimated by the Base model for the surveys (upper panel) and fisheries (lower panel).

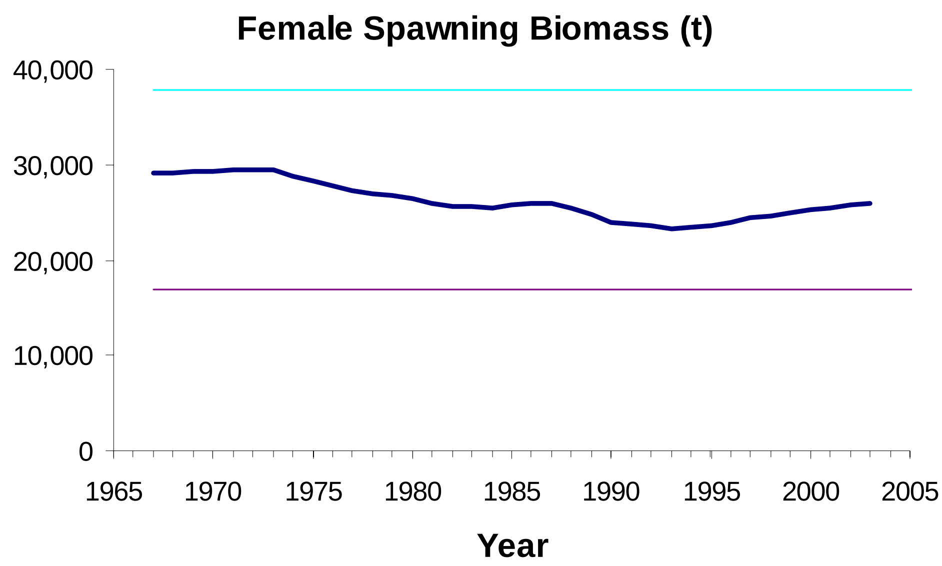


Figure 12.12. Base model estimated female spawner biomass trajectory (heavy line) for shortspine thornyheads in the Gulf of Alaska. Upper straight line is unfished biomass, lower straight line is $B_{35\%}$ (as defined from average year-class estimates since 1977).

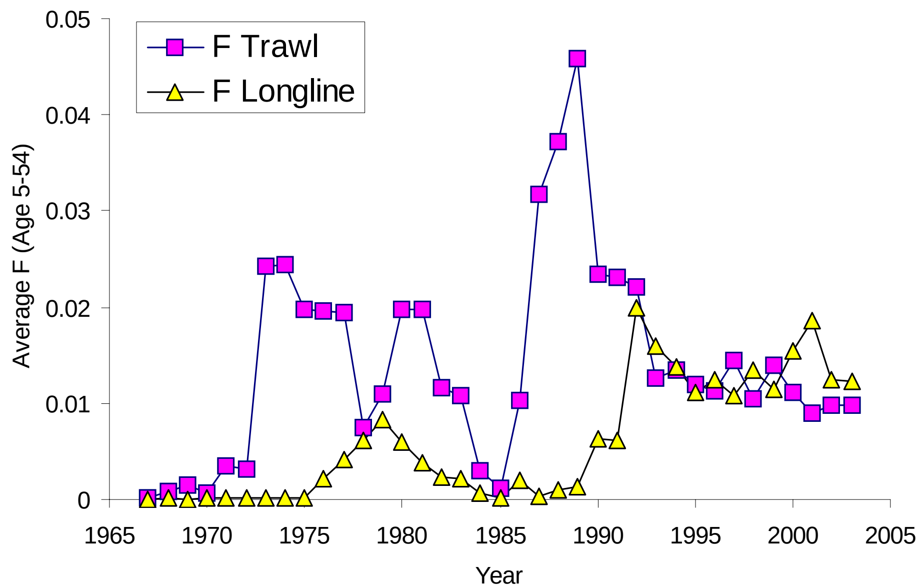
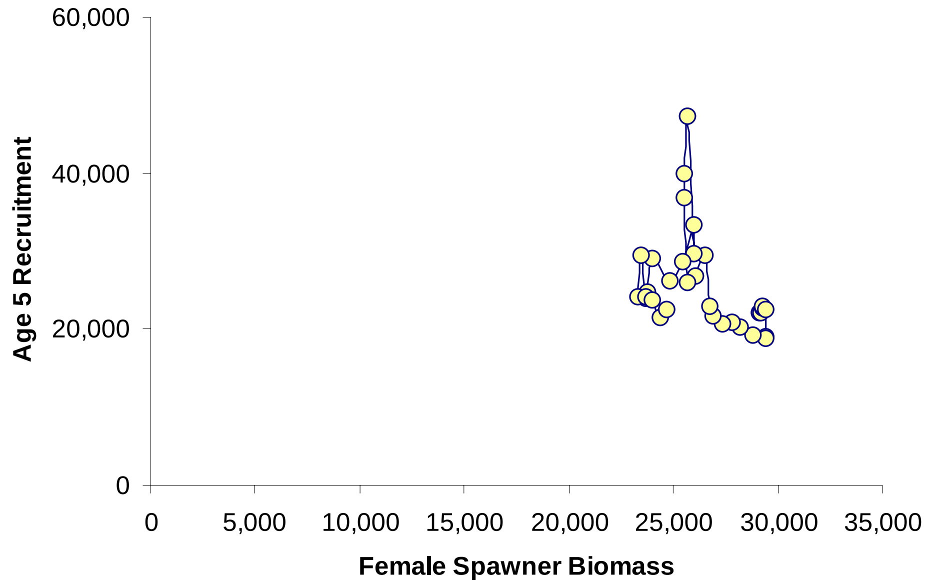


Figure 12.13. Base model average (over ages 5-54) fishing mortality rate by gear type on shortspine thornyheads in the Gulf of Alaska, 1967-2003.



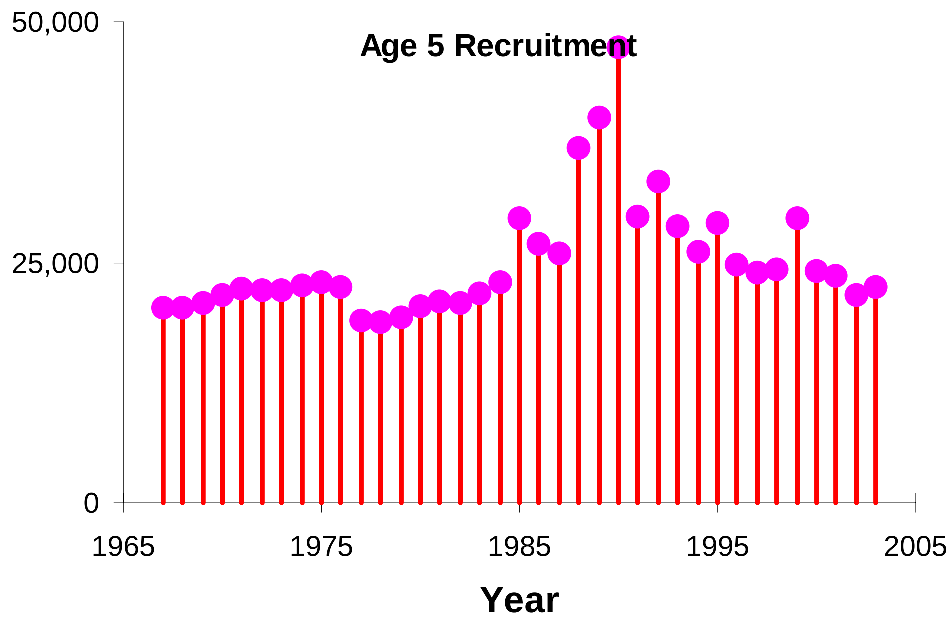


Figure 12.14. The stock-recruitment plot (upper panel) and time series of recruitment strengths (lower panel) from the base model for shortspine thornyheads in the Gulf of Alaska.

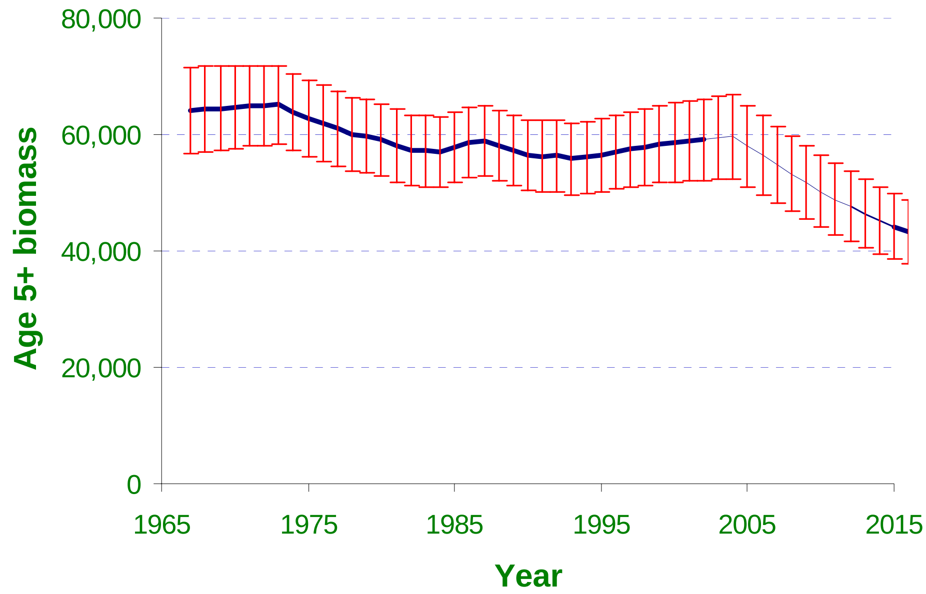


Figure 12.15. Base model historical and projected shortspine thornyhead age 5+ biomass with 2 standard deviations. Note that future projections are based on an assumed $F_{40\%}$ fishing mortality rate.

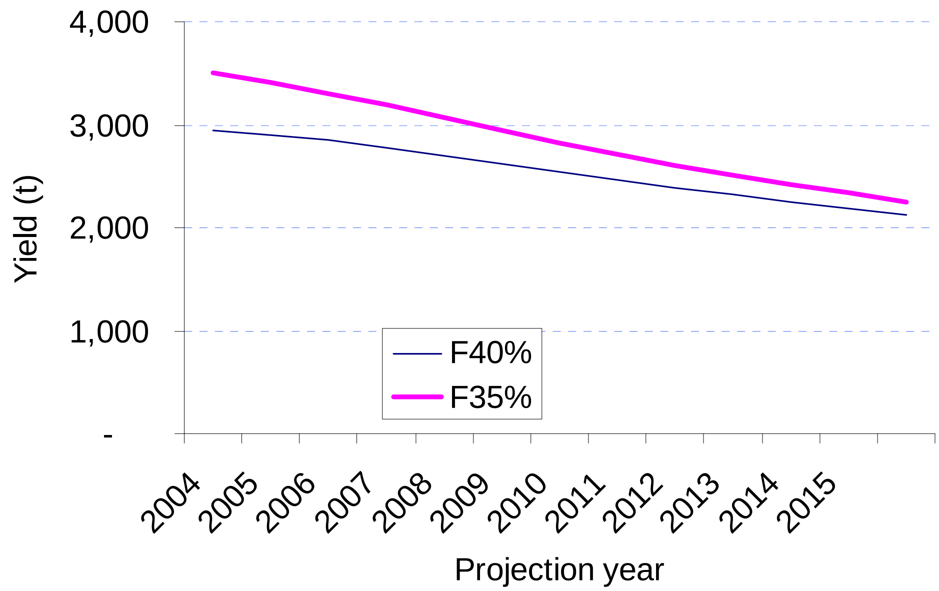


Figure 12.16. Base model projected future yield of shortspine thornyheads under alternative SPR fishing mortality rates.

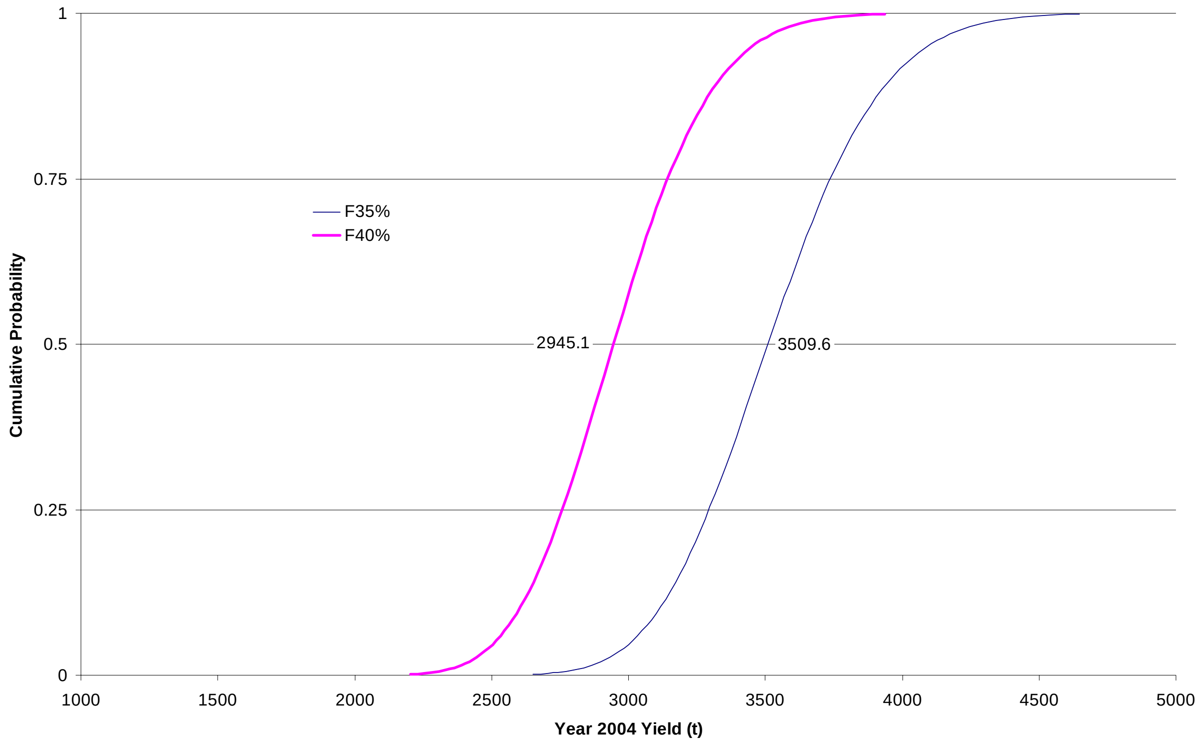
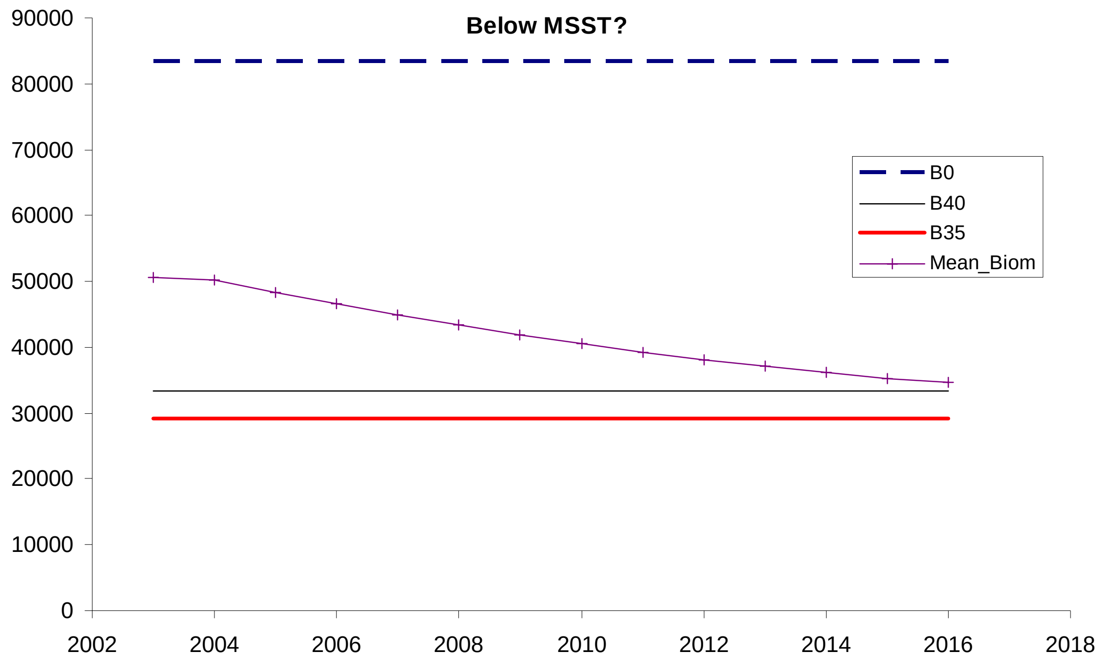


Figure 12.17. Base model projected 2004 shortspine thornyhead yield under alternative SPR harvest rates. The cumulative probability reflects uncertainty in the current stock size in addition to uncertainty in estimating the SPR rates themselves.



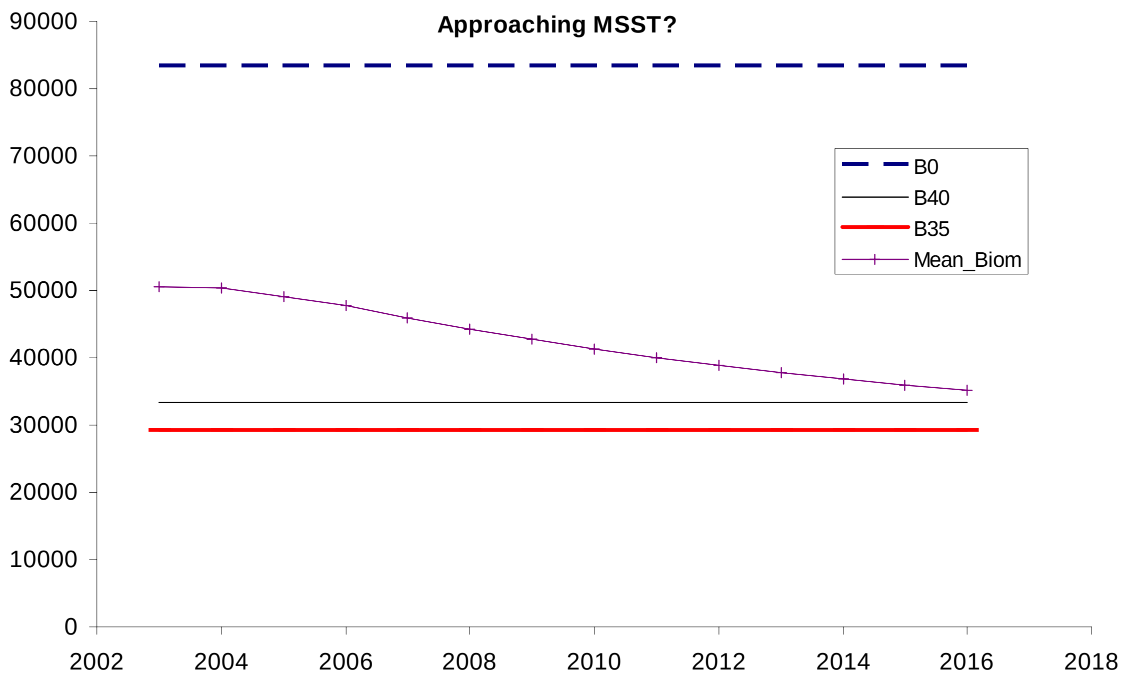


Figure 12.18. Base model projected shortspine thornyhead female spawning biomass under two scenarios. Top panel (scenario 6 in text): In all future years, F is set equal to F_{OFL}. Bottom pane (scenario 7 in text): In 2004 and 2005, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}.